HOUSEHOLD RISKY ASSET CHOICE:

AN EMPIRICAL STUDY USING BHPS

by

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Abstract

Using the BHPS data, we have carried out three empirical studies to investigate household risky asset choice in the UK. In the first study we follow appropriate econometric procedures to identify household specific factors that can be observed to influence a household's asset choice through parameters of their objective function, such as risk aversion and habit. In the second and third study, we use techniques to explain the specific influence of various factors rather than finding what lies behind the interactions observed. Specifically, the second study is about examining the effect of retirement on household risky asset choice and investigating whether this effect would be different when house ownership is taken into account. In fact, we do find that retirement has a positive effect on risky asset shares for house owners while it has no effect on non-house owners. In the third study, we carry out an empirical study on the impact of taxation on household risky asset choice, and we find in the short run paying income tax has negative impact on individual's risky asset shares and in the long run paying capital gain tax has positive effect on individual's risky asset shares. Hence a possible policy implication is to increase the income tax allowance in order to provide incentives for people on low incomes to save, and to save in a balanced portfolio of low and high risk assets.

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1 Introduction

1.1 Research background

Suppose we have an individual who has a certain amount of initial wealth. Typically, this individual needs to make two important decisions. As a consumer, he/she needs to decide how much of his/her wealth and income should be spent on current consumption and how much should be saved for future consumption. As an investor, he/she needs to determine the allocations of his/her savings among different assets. These two decisions are called the consumption-saving decision and the portfolio allocation decision respectively (Constantinides and Malliaris, 1995).

Empirically, we observe cross-sectional variation in household [1] portfolio allocations. If we want to explain this heterogeneity in household portfolio allocations in a classical "utility maximizing framework", we "must" refer to "heterogeneity in circumstances, heterogeneity in preferences or a combination of the two" (Curcuru *et al.* 2004, p2). The "heterogeneity in circumstances" means each household has his/her own circumstance that differs from others in terms of demographics (eg: age, employment status, wealth, education), "non-diversifiable background risks" (eg: labour income risk, entrepreneurial income risk, house price risk), information asymmetries and transaction costs (eg: brokerage fees and psychic cost) (Curcuru *et al*. 2004, p2). This "heterogeneity in circumstances" could lead to the cross-sectional variation in

[1] In my thesis, the term of households and individuals are interchangeable, and both of them refer to individuals.

household portfolio allocations. On the other hand, many scholars work on preference-based theories to solve the optimal intertemporal consumption /portfolio allocation problem, for example, the early work introduced by Merton (1969), and Samuelson (1969, 1970), habit formation related model developed by Gomes and Michaelides (2003), Munk (2008), Polkovnichenko (2007), Gupta (2009), Lax (2002), and stochastic hyperbolic preferences based model developed by Palacios-Huerta and Pérez-Kakabadse (2011).

1.2 Research motivations

In this section, we provide our motivation of why we decide to study household's risky asset choice in the UK and focus on why the UK is an interesting case study.

The motivation for the thesis is that portfolio allocation generally and risky-asset selection more specifically is an important topic for research. The thesis is particularly focussed on factors that influence portfolio selection which might be described as reflecting social and behavioural as well as economic influences. Hence the thesis adds to our understanding of what are the important determinants of portfolio choice beyond those found in standard models (where risk, return and (exogenous) attitude to risk) are the crucial determining variables.

There are a number of implications which make the research in the thesis interesting. Firstly the assets that individuals hold in their wealth will influence the structure of financial markets and institutions and of the returns that are generated. Secondly understanding the factors that influence the structure of individual portfolios will give us insight into what determines the demand for financial assets. Thirdly examining how various government policy variables, such as income tax and capital gains tax on portfolio choice will help us to understand the impact of policy.

The focus on the UK recognises that we have the most developed financial sector of any European Economy and that there is a much greater emphasis placed on stock markets as a source of finance for industry. Hence analysing the demand for risky assets, which is mainly shares, is of particular significance.

1.3 Research aim and research questions

The aim of this research is to provide an explanation for the cross-sectional variation in household risk asset choice by using the British Household Panel Survey data (BHPS). We follow appropriate econometric procedures to identify factors that influence household risk asset choices and explain the results in the context of risk aversion and habit.

The economic analysis of portfolio choice identifies that risk aversion, the subjective distribution of asset returns, and the stochastic relationship of returns to labour income are central to households' asset choices. When transaction costs and taxes are taken into consideration, these two factors will also have effects on asset choice. There are a number of issues which can be analysed by applying this general analytical framework to the UK Household Survey dataset. In this thesis, we work on the British Household Panel Survey, and will draw some valuable conclusions. Specifically, we have the following research questions:

1) Are household social and economic demographics able to explain the cross-sectional variation in household risk asset choice? Under certain

assumptions, can we interpret the household characteristics effects in the context of risk aversion and habit?

2) Does retirement have an impact on households' risky asset allocation? When we answer this question, does home ownership need to be taken into account?

3) Does taxation have an impact on the households' risky asset allocation? If so, what policy conclusion can we draw?

1.4 Research contributions

Partly due to the limitation of datasets on households' asset holdings, limited work has been undertaken on household asset choices, especially in the UK. In this thesis, we will carry out an analysis on British households' risky asset choices by using the British Household Panel Survey (BHPS) data, in particular, survey data for the years 1995, 2000 and 2005. As far as we know, the BHPS is the most appropriate[2] secondary dataset which provides detailed information on households' social and economic demographics, and this dataset has not been used to examine the household risky asset choice yet.

We use data from 1995 and 2000 for all of studies. We also use 2005 for the third study. We do not use 2010 since this data only became available after the bulk of the research was completed. The choice of data is determined by the type of work we wish to undertake. Thus when we are looking at household specific determinants of portfolio choice we prefer to use a limited data set to allow us to focus at the household level and not get involved too much in controlling for factors which change over time. For the

[2] Except Wealth and Assets Survey which became available last year. We propose to use this new dataset for future research.

impact of tax changes we do use 2005 data since the difference in difference estimation method allows us to control for time effects relatively easily.

We also contribute the existing literature by applying two econometric methods, namely, censored quantile regression (CQR) and Difference-in-Difference estimation (DD). The CQR method is a recent econometric method. Unlike OLS or Tobit estimation, which considers the conditional mean, CQR estimates the effect of explanatory variables at different quantiles of the distribution of the error term. This estimator "is consistent and asymptotically normal for a wide class of error distributions, and it is robust to heteroscedasticity"(Powell, 1986; cited in Billett and Xue, 2007, p1841). Although CQR have received much attention both in the theoretical and empirical studies, it has not been used in the research topic of households' risky asset choice. Therefore, we carry out further analysis by using CQR and contribute to the existing literature.

Although Stephens and Ward-Batts (2004) used DD estimation method to examine how British couples responded to the tax system changes from joint to independent in the UK in 1990. Alan *et al*. (2010) used DD estimation method to examine how Canadian couples responded to the tax system changes from joint to independent in Canada in 1988, they focused on the reallocation of asset ownership within couples rather than focusing on the effect of taxation on individual's risky asset allocation. In addition, we not only use the DD method to examine the marginal tax rate effect but also the income allowance effect, which is novel to the existing literature.

1.5 Thesis structure

The structure of this thesis is as follows.

In Chapter Two, we provide a literature review on households' consumption/ portfolio choice models. We start from a one period consumption/portfolio allocation model, followed by inter-temporal models. After that we examine whether the proportion of these models are consistent with the empirical observations. Then we follow Carroll's (2011) approach, introduce stochastic labour income into the model and carry out a simulation. However, the simulation results still could not explain the empirical observations. In contrast, incorporating habit formation in consumption into the model can improve the explanatory power of the theoretical model significantly. Finally, we review the recent studies which examine the effect of housing, transaction cost and taxation on household asset allocation.

In Chapter Three, we analyse empirically household-specific factors that influence the extent to which household hold risky assets. Assuming zero transaction costs and taxes and that subjective expectations are homogenous across households or the difference is random implies that risk aversion is the main driver behind different portfolio choices across households. Using a typical model of asset choice, our empirical specification identifies variables that can be observed to influence a households' asset choice through parameters of their objective function such as risk aversion and habit. We interpret the results in this context. Net liquid wealth, personal debt, housing wealth, outstanding mortgage, the ratio of income to net liquid wealth, age and employment status are observed to influence a household's risk aversion. Factors such as education, pension, gender, marital status, number of children and location are found to be insignificant variables. Furthermore, when we look at household level data an important feature is that a significant proportion of households hold no risky assets (specifically equity). This implies particular econometric procedures to undertake research on risky asset choice. In this chapter, we use Tobit estimation methods and censored quantile regression (CQR) which are supposed to be the most appropriate econometric procedures.

In Chapter Four, we investigate how the portfolios of British households evolve leading up to and beyond retirement. Using data from the British Household Panel Survey (BHPS), we examine the impact of retirement and housing ownership on the share of a household's total assets held in risky assets. By carrying out cross-sectional analysis, we find that house owners increase their risky asset portfolio as they just entered their retirement stage or as they are in the early stage of their retirement. However, no effect of retirement on risky asset shares could be found for non-house owners. By running Difference-in- Differences (DD) regression, we also find a positive impact of retirement on risky asset shares. Furthermore, by implementing a short panel study on the joint impact of retirement and housing ownership, we find that on average, retired house owners hold the highest proportion of risky assets among the four categories of households defined in the paper, followed by employed house owners who hold the second highest proportion of risky assets. The average risky asset shares of the other two categories of households, namely, retired non-house owners and employed non-house owners are relatively the same and are the lowest among all. These results are statistically significant.

In Chapter Five, the impact of taxation is considered in detail using household level datasets. We examine the impact of tax allowances and marginal tax rates on portfolio shares in risky assets by using the Difference-in-Difference method. After controlling for demographic factors, we find in the short run paying income tax has negative impact on individual's risky asset shares, which is significantly different from zero at 1 percentage level. We also find in the long run paying capital gain tax has positive effect on individual's risky asset shares, which is also significantly different from zero at 1 percentage level. In contrast, by using DD estimation methods, we find neither marginal income tax rate nor marginal capital gain tax has effect on risky asset shares. Furthermore, this null effect of marginal tax on risky asset shares has also been found in the standard Tobit regression for 2000 when we followed Poterba and Samwick's (2003) method and calculated the marginal tax rate for each individual.

2: Theoretical Considerations and Literature Review

Early work on portfolio theory was set in a static one period setting (Markowitz, 1952, Tobin, 1958) and involved maximising a utility function of wealth. The principles established in that work were incorporated into dynamic specifications (Samuelson (1969) and Merton (1969, 1971)). Samuelson (1969) and Merton (1969, 1971) determined the optimal policies for portfolio allocation in a discrete-time setting and a continuous-time setting respectively.

In this chapter, we first look at a one-period consumption/portfolio allocation model followed by inter-temporal consumption/portfolio choice models. In particular, we look at the models developed by Samuelson (1969) Merton (1969). Then we examine whether the propositions of these models are consistent with the empirical observations. In section 2.4, we study a consumption/portfolio model with time varying labour income. We set up the model following Carroll's (2011) approach, and present the simulation results in section 2.4.3. Later, we review recent development in portfolio theory, for example, models incorporating habit formation in consumption. We hope to see that introducing habit formation into the model could explain the empirical observations of low levels of risky assets shares. Similarly, a two-period model with habit formation is examined in the first place followed by a discrete life-cycle model and a continuous life-cycle model with habit formation. The explanatory power of these models is also investigated. The last section of this chapter review the recent studies which examine the effect of housing, transaction cost and taxation on household asset allocation.

2.1 One-period consumption/portfolio allocation model

2.1.1 Basic assumptions for the market

Before we set up the one-period consumption/portfolio allocation model, we present the basic assumptions for the financial market first. The following four assumptions have been assumed in the early models, both in the static one-period model or inter-temporal consumption/portfolio choice models, such as Samuelson (1969) and Merton's (1969) models:

Assumption 1: Complete market

Short sales are allowed for all assets. There are no borrowing constraints on riskfree asset and the borrowing rate is equal to the lending rate.

Assumption 2: No market frictions

No participation cost, transaction cost and/or taxes in this basic model.

Assumption 3: Price taker

The representative agent is a price taker and his/her investment decision does not affect the assets' prices and returns. His/her optimal portfolio allocation is only determined by his/her utility function. It is independent from the demand for and supply of the assets in the market.

Assumption 4: No-arbitrage opportunities

All the risk-free assets and risk-free portfolio generate a common and constant return which is denoted as R^F.

2.1.2 Additional assumptions for the one period consumption/portfolio allocation model

In addition to the above basic assumption for the market, we also assume that the representative agent only receives income from investment and receives no labour income. There are two assets in the market, namely a risk-free asset and a risky asset. The former has a constant one-period gross return which is denoted as R^F. The one period gross return on the latter asset is random and is denoted as R_{t+1}. We define a portfolio as any linear combination of these two assets which provides a positive market value. In the one-period model, the individual needs to decide the optimal consumption level and optimal risky asset share at the beginning of the period, which is denoted as time t, and consume all the remaining wealth at the end of the period, which is denoted as time $t+1$, in order to maximize his expected utility from consumption over time t and time $t+1$. The utility function is denoted as $U(C_t)$ and $U(C_{t+1})$. Furthermore, the utility function is assumed to be "an increasing strictly concave function on the range of feasible values" for C_t and C_{t+1} and "it is twice continuously differentiable" [3](Merton, 1999, p17).

2.1.3 The one period consumption/portfolio allocation model

The objective function for the one-period portfolio allocation model is as follows[4]:

$$\max_{\{C_t,\alpha_t\}} E_t\ [U(C_t) + \beta U(C_{t+1})]$$

subject to

$$C_t = [W_t - \frac{W_{t+1}}{R^F(1-\alpha_t) + R_{t+1}\alpha_t}]$$

where W_t is the initial wealth, in other words the total wealth owned by the investor at the beginning of a period (ie: at time t); C_t is the consumption level at time t, and α_t is the proportion of liquid wealth invested in the risky asset. The individual needs to decide C_t and α_t simultaneously. W_{t+1} is the total remaining wealth at time *t+1*, which will all be consumed at time *t+1*. There is no bequest motive in this model.

Hence we can rewrite our objective function as follows:

$$\max_{\{C_t,\alpha_t\}} \{U(C_t) + E\beta U[(W_t - C_t)(R^F(1-\alpha_t) + R_{t+1}\alpha_t)]\}$$

Taking partial derivative of this objective function with respect to C_t and α_t respectively, we will have the first-order conditions:

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[3] The assumption of strict concave utility function implies that the investor is everywhere risk averse (Merton, 1999, p17).

[4] We follow Samuelson (1969) and Merton (1969) to develop this one period model.

$$0 = U'(C_t) - \beta E U'(C_{t+1})[R^F(1-\alpha_t) + R_{t+1}\alpha_t]$$

$$0 = EU'(C_{t+1})(W_t - C_t)(R_{t+1} - R^F)$$

$$= \int_0^\infty U'\{(W_t - C_t)[R^F(1-\alpha_t) + R_{t+1}\alpha_t]\}(W_t - C_t)(R_{t+1} - R^F)dP(R_{t+1})$$

where $P(R_{t+1})$ stands for the probability density function of variable R_{t+1}.

In the case of isoelastic utility case, $U(C_t) = C_t^{1-\gamma}/(1-\gamma)$, we solve these FOCs simultaneously, and derive the optimal consumption and portfolio allocation decisions for time *t*, namely, C_t^* and α_t^*, as follows:

$$C_t^* = \frac{b_1}{1+b_1} W_t$$

where $b_1 = \{\int_0^\infty [(1-\alpha_t^*)R^F + \alpha_t^* R_{t+1}]dP(R_{t+1})\}^{\frac{1-\gamma}{-\gamma}} \beta^{\frac{1}{-\gamma}}$

and

α_t^* is a solution to

$$0 = \int_0^\infty [(1-\alpha_t^*)R^F + \alpha_t^* R_{t+1}]^{-\gamma} (R_{t+1} - R^F)dP(R_{t+1}),$$

where $P(R_{t+1})$ is the probability density function of variable R_{t+1}.

As we can see, this result suggests that in the one-period optimal consumption/portfolio model, the optimal portfolio allocation rule is independent of consumption decisions and it is also independent of wealth.

2.2 Inter-temporal consumption/portfolio choice models (Samuelson, 1969 and Merton, 1969)

After deriving the optimal consumption rule and optimal asset allocation rule for the one period model, in this section, we review the inter-temporal consumption/portfolio choice models, specifically, Samuelson's discrete time model (Samuelson, 1969) and Merton's continuous time model (Merton, 1969).

2.2.1 Samuelson's model (1969)

In Samuelson's model (1969), an individual needs to decide his/her optimal consumption rule and optimal portfolio allocation rule in a finite discrete time setting. The assumptions for Samuelson (1969) are similar to the one-period consumption/portfolio choice model we set up in the above section 2.1. In the two-asset case, the objective function is as follows:

$$\max_{\{C_t,\alpha_t\}} E_t \sum_{t=0}^{T} \beta^t \, U(C_t)$$

subject to

$$C_t = [W_t - \frac{W_{t+1}}{R^F(1-\alpha_t) + R_{t+1}\alpha_t}]$$

In this dynamic programming problem, Samuelson (1969) started with the last period and then applied recursive methods. The value function for time *T-1* is as follows:

$$V_{T-1}(W_{T-1}) = \max_{\{C_{T-1},\alpha_{T-1}\}} U(C_{T-1}) + E\beta U\{(W_{T-1} - C_{T-1})[R^F(1-\alpha_{T-1}) + R_T\alpha_{T-1}]\}$$

(1)

Taking the partial derivative of this value function with respect to C_{T-1} and α_{T-1} respectively, and solving FOCs simultaneously, he derived the optimal consumption and portfolio allocation decisions for time *T-1*, namely, C^*_{T-1} and α^*_{T-1}. Substitute C^*_{T-1} and α^*_{T-1} into equation (1) and get $V_{T-1}(W_{T-1})$. By applying envelop theorem: $V'_{T-1}(W_{T-1}) = U^{'}(C_{T-1})$ and knowing $V_{T-1}(W_{T-1})$, he wrote out the value function for one period earlier:

$V_{T-2}(W_{T-2}) = {}_{\{C_{T-2},\boldsymbol{\alpha_{T-2}}\}}^{\ \ \ \ max} U(C_{T-2}) + E\beta V_{T-1}\{(W_{T-2} - C_{T-2})[R^F(1-\alpha_{T-2}) +$
$R_{T-1}\alpha_{T-2}]\}$.

Then take the partial derivatives, set up the FOCs, derive the functions for C^*_{T-2} and α^*_{T-2} and determine $V_{T-2}(W_{T-2})$. By using this recursive method and working backwards in time, the optimal consumption and portfolio allocation rules can be solved.

In the case of the isoelastic utility case, $U(C_t) = C_t^{1-\gamma}/(1-\gamma)$, the optimal consumption rule is in the form of $C^*_{T-i} = c_i W_{T-i}$[5], and the optimal portfolio allocation rule, α^*_t is constant, and it is a solution to

$$0 = \int_0^\infty [(1-\alpha^*_t)R^F + \alpha^*_t R_{t+1}]^{-\gamma}\,(R_{t+1} - R^F)dP(R_{t+1}),$$

where $P(R_{t+1})$ is the probability density function of variable R_{t+1}.

As we can see, the results of Samuelson's (1969) model not only suggests that the optimal portfolio allocation rule is independent of consumption decisions and

[5] For details about the optimal consumption rules, please see Samuelson's 1969 paper on page 244.

independent of wealth, but also suggests that the optimal portfolio allocation rule is independent of the investment time horizon.

2.2.2 Merton's model (1969)

Different from the discrete time settings in Samuelson's (1969) model, in Merton's (1969) model an individual needs to decide his/her optimal consumption rule and optimal portfolio allocation rule in a continuous time setting.

The assumptions are similar to the assumptions in Samuelson (1969) except the followings. The returns of those risky assets are stochastic which follow the "Wiener Brownian-motion process" (Merton, 1969, p247). In particular, he sets up a two-asset model in which the agent is allowed to invest, namely, a risk-free asset with "a constant rate of return" and a stochastically-risky asset with "a constant equity risk premium" (McCarthy, 2004, p10). The representative agent's objective is to maximize his/her expected value of discounted lifetime utility from consumption and discounted terminal wealth. The objective function is as follows:

$$max\ E[\int_0^T e^{-\delta t}\, U(C_t)dt + e^{-\delta T}U(W_T)] \tag{2}$$

subject to budget constraint $dW_t = \{[R^F + \alpha_t(R - R^F)]W_t - C_t\}dt + \alpha_t \sigma W_t dB_t$,

$C_t \geq 0;\ W_t > 0; W_{t=0} = W_0 > 0;$

where

δ: subjective discount rate

C_t: level of consumption at time t

$U(C_t)$: utility of consumption at time t

W_T: level of wealth at terminal time T

$U(W_T)$: utility of terminal wealth

W_t: level of wealth at time t

R^F: gross return on the risk-free asset which is constant overtime

R: expected gross return on the risky asset which is constant overtime

σ: standard deviation of the gross return on the risky asset which is constant overtime

α_t: the proportion of the portfolio invested in the risky asset between time t and $t+1$

dB_t: the increment of the Wiener process

Additionally, the representative agent in this model is assumed to have a utility function with CRRA, $U(C_t) = C_t^{1-\gamma}/(1-\gamma)$ and $U(W_T) = W_T^{1-\gamma}/(1-\gamma)$ and γ refers to coefficient of relative risk aversion. As we can see from Merton's model, given a constant value of R^F, R and σ, the investment opportunities are not time-varying. This assumption was relaxed in later models (Merton, 1971, 1973).

Now, by using the Bellman equation we rewrite the model as follows:

$$V_t(W_t) = \max_{\{C_t,\boldsymbol{\alpha_t}\}} E_t\left[\int_t^T e^{-\delta t} U(C_t)dt + e^{-\delta T} U(W_T)\right]$$

and it is subject to all the constraints listed above. In general, we can write it as:

$$V_{t_0}(W_{t_0}) = \max_{\{C_t,\boldsymbol{\alpha_t}\}} E_{t_0}\left[\int_{t_0}^t e^{-\delta t} U(C_t)dt + V_t(W_t)\right] \tag{3}$$

In particular, we can write:

$$V_0(W_0) = \max_{\{C_t,\boldsymbol{\alpha}_t\}} E_0[\int_0^t e^{-\delta t} U(C_t) dt + V_t(W_t)]$$

If $t = t_0 + \Delta$ and "the third partial derivatives" of $V_{t_0}(W_{t_0})$ are bounded, we can use "Taylor's theorem and the mean value theorem for integrals" to rewrite (3) as

$$V_{t_0}(W_{t_0}) = \max_{\{C_t,\boldsymbol{\alpha}_t\}} E_{t_0}\{e^{-\delta \bar{t}} U(C_t) + V_{t_0}(W_{t_0}) + \frac{\partial[V_{t_0}(W_{t_0})]}{\partial t} + \frac{\partial[V_{t_0}(W_{t_0})]}{\partial W}(W_t - W_{t_0})$$

$$+\frac{1}{2!}\frac{\partial^2[V_{t_0}(W_{t_0})]}{\partial W^2}(W_t - W_{t_0})^2 + 0(\Delta^2)\} \tag{4}$$

where $t_0 \leq \bar{t} \leq t$.

On the right-hand side of equation (4), if we take the E_{t_0} operator into each term, then $V_{t_0}(W_{t_0})$ on the left-hand side and $E_{t_0}V_{t_0}(W_{t_0})$ on the right-hand side can cancel each other out. Since $E_{t_0}(W_t - W_{t_0}) = \{[\alpha_{t_0}(R - R^F) + R^F]W_{t_0} - C_{t_0}\}\Delta + 0(\Delta^2)$ and $E_{t_0}[(W_t - W_{t_0})^2] = \alpha_{t_0}^2 W_{t_0}^2 \sigma^2 \Delta + 0(\Delta^2)$, if we substitute these two equations into equation (4) and then divide both sides of the equation by Δ, and take the limit of this derived equation as $\Delta \rightarrow 0$, we will get the following equation:

$$0 = \max_{\{C_t,\boldsymbol{\alpha}_t\}}\{e^{-\delta t} U(C_t) + \frac{\partial[V_t(W_t)]}{\partial t} + \frac{\partial[V_t(W_t)]}{\partial W}[(\alpha_t(R - R^F) + R^F)W_t - C_t]$$

$$+\frac{1}{2}\frac{\partial^2[V_t(W_t)]}{\partial W^2}\alpha_t^2 W_t^2 \sigma^2\} \tag{5}$$

where $0 \leq t \leq T$.

So if we define $f(C, \alpha; W; t) = \{e^{-\delta t} U(C_t) + \frac{\partial[V_t(W_t)]}{\partial t} + \frac{\partial[V_t(W_t)]}{\partial W}[(\alpha_t(R - R^F) + R^F)W_t - C_t] + \frac{1}{2}\frac{\partial^2[V_t(W_t)]}{\partial W^2}\alpha_t^2 W_t^2 \sigma^2\}$, then equation (5) becomes as follows:

$0 = \max_{\{C,\alpha\}} f(C, \alpha; W; t).$

Hence we can write out the optimality conditions (Merton, 1969):

$$\begin{cases} f(C^*, \alpha^*; W; t) = 0 \\ f_C(C^*, \alpha^*; W; t) = 0 \\ f_\alpha(C^*, \alpha^*; W; t) = 0 \\ \text{subject to the boundary condition } V_T(W_T) = e^{-\delta T} U_T(W_T) \textit{ and the solution being} \\ \textit{a feasible solution to equation } (2). \end{cases}$$

Under the additional assumption of having a utility function with CRRA, an explicit solution can be obtained. If we assume $U(C_t) = C_t^{1-\gamma}/(1-\gamma)$ and $U(W_T) = W_T^{1-\gamma}/(1-\gamma)$, the optimal consumption and portfolio allocation rules in the two-asset case are as follows (Merton, 1969):

$$\alpha_t^* = \frac{R - R^F}{\sigma^2 \gamma} \equiv \alpha^* \tag{6}$$

and $C_t^* = \frac{R}{\gamma}[1 + \left(\frac{R}{\gamma}\varepsilon - 1\right) e^{-\frac{R}{\gamma}(T-t)}]^{-1} W_t$, for $\frac{R}{\gamma} \neq 0$;

$C_t^* = [T - t + \varepsilon]^{-1} W_t$, for $\frac{R}{\gamma} = 0$, where $0 < \varepsilon \ll 1$.

If no bequests are introduced in the model (ie: $\varepsilon = 0$), then the optimal portfolio allocation rule remains the same as equation (6) and the optimal consumption rule becomes:

$C_t^* = \frac{R}{\gamma}[1 + (-1)e^{-\frac{R}{\gamma}(T-t)}]^{-1} W_t$, for $\frac{R}{\gamma} \neq 0$;

$C_t^* = [T - t]^{-1} W_t$, for $\frac{R}{\gamma} = 0$.

If a logarithmic utility function is assumed (ie: $\mathrm{U(C_t)} = \log(\mathrm{C_t})$ and $U(W_T) = log\,(W_T)$), then the optimal portfolio allocation rule still remains unchanged as equation (6) and the optimal consumption rule becomes:

$$C_t^* = \delta[1 + (\delta\varepsilon - 1)e^{-\delta(T-t)}]^{-1}W_t.$$

As we can see, under the assumptions of constant investment opportunities and a utility function with CRRA, the optimal portfolio allocation rule is independent of his/her consumption choice, the investment time horizon or age and the investor's wealth (Merton, 1969). The representative agent invests a constant proportion of wealth in risky asset over his/her life time. These results are consistent with the findings in the Samuelson's model with discrete time settings which we presented in the above section 2.2.1.

2.3 The limitations in Merton's portfolio allocation model

2.3.1 Limited closed-form solution to Merton's portfolio allocation

There is a limited closed-form solution to Merton's portfolio allocation problem. Merton (1971) stated that due to the "basic nonlinearity of the equations and the large number of state variables" (Merton, 1971, p384), the optimum consumption and portfolio rules in a continuous-time model cannot be solved completely unless "when asset prices satisfy the 'geometric' Brownian motion hypothesis and the individual's utility function is a member of the HARA family, the consumption-portfolio problem is completely solved" (Merton, 1971, p394) or "for a particular member of the HARA family, namely the Bernoulli logarithmic utility function, the optimal rules can be solved explicitly for general price mechanism" (Merton, 1971, p403).

However, if we assume log utility function for the representative agent, then "different assumptions about price behaviour have no effect on the decision rules" (Merton, 1971, p403). In other words, this agent will not "be concerned about hedging against shifts in the future investment opportunity set (changes in expected returns or covariances)" (Brennan *et al.,*1997, p1378), because "for the special case of Bernoulli logarithmic utility (γ = 1)", not only "the portfolio-selection decision is independent of the consumption decision", but also "the consumption decision is independent of the financial parameters and is only dependent upon the level of wealth" (Merton, 1969, p253). Therefore, if that is the case, the dynamic portfolio problem will become a static one which would seem not to solve the problem addressed originally (Campbell *et al.* 2003).

2.3.2 The failure of Merton model in explaining empirical observations

The following Table 2.1 presents the optimal asset allocation rules for 9 countries, under the assumption that the investment opportunities are constant over time and the investor has a CRRA utility function with $\gamma = 1$ (the log utility case), $\gamma = 3$ and $\gamma = 5$. Then the equity portfolio share is constant and equals to $\frac{R-R^F}{\sigma^2\gamma}$, which follows the portfolio rule derived by Merton (1969, 1971). The real returns and volatilities that we used here were calculated by Jorion and Goetzmann (1999).

As we can see, the predicted optimal equity portfolio shares for those 9 countries in Table 2.1 seem to be too high when we compared them with the empirical observations (Guiso *et al*., 2002; McCarthy, 2004; Iwaisako, 2009), except for Italy. Table 2.1 shows that the real return from risky investment in Italy is about 3.2 % which is lower than 5.5% in the US, whereas in Italy the volatility of equity returns which is measured by variance is nearly two times higher than that in the US. Hence, with relatively low real return and high volatility, the predicted risky portfolio share in Italy is just 16% if γ = 3 and 10% if γ = 5. The results in this table, thus, partially demonstrate that the traditional Merton-Samuelson model (1969) predicts a much higher households' risky asset allocation. In addition, these results also present the equity premium puzzle from the portfolio perspective, in other words, why the actual risky portfolio shares is much lower than the predicted optimal one giving the realistic values on risk and return as well as reasonable assumptions on an individual's preference (McCarthy, 2004).

Table2. 1: Merton-Samuelson Asset Allocation for 9 Countries

	US	Japan	UK	Canada	Australia	Germany	Switzerland	Netherland	Italy
Period	1/1921-12/1996	4/1949-12/1996	1/1921-12/1996	1/1921-12/1996	1/1931-12/1996	1/1950-12/1996	1/1926-12/1996	1/1921-12/1996	12/1928-12/1996
Real return	5.5%	7.2%	3.6%	4.5%	2.6%	7.6%	4.3%	2.8%	3.2%
Volatility	2.5%	3.6%	2.5%	2.8%	1.9%	2.4%	2.2%	2.2%	6.6%
Equity portfolio share (γ=1)	220.0%	200.0%	144.0%	160.7%	132.3%	316.7%	197.3%	127.3%	48.5%
Equity portfolio share (γ=3)	73%	67%	49%	54%	44%	104%	66%	42%	16%
Equity portfolio share (γ=5)	44%	40%	29%	32%	26%	62%	39%	25%	10%

Source: McCarthy (2004) and author's own calculations, using the values of real return and volatility derived by Jorion and Goetzmann (2000).

The real returns and volatilities are measured in local currency and in real terms (Jorion and Goetzmann, 2000).

The classical Merton-Samuelson model not only fail to explain the relatively low proportion of households' wealth invested in risky assets, which can be seen from Table

2.1, but also fail to explain the "age–portfolio profile" that have been widely observed in the real world. Merton (1969) and Samuelson (1969) predicted that the optimal risky portfolio share should be constant for the finite as well as the infinite investment horizon under certain assumptions including individual preference with CRRA, constant investment opportunities or the individual with log utility function, and no labour income is generated. This implies that in theory age and wealth have no impact on the optimal risky portfolio share. However, in general, an inverse-U shape of age effect on individual's risky asset allocation has been found in a wide range of empirical studies. For example, Ameriks and Zeldes (2004) investigated the household asset allocation behaviour in the US and find that unconditional risky portfolio shares have "a hump-shaped relationship to age" by using the Surveys of Consumer Finances data from 1989 to 1998. Similar patterns have also been found in the European countries such as the UK, Netherlands, Germany, Italy (Guiso *et al.,* 2002) and in Japan (Iwaisako, 2009). On the contrary, the investment specialists typically would give a suggestion that is different from the classical portfolio theory. They suggested investors who are at the early stage of their lifecycle should invest a large proportion of their wealth, mainly labour income, in risky assets, in order to take advantage of the equity risk premium. As the investment time horizon shrinks, the middle-aged investors would be suggested to hold a portfolio with modest risk and not surprisingly, older investors would be advised to invest most of their wealth in risk-free assets (Bali *et al.,* 2009). Furthermore, Malkiel (1999), a financial specialist, has established an easy way to calculate the individual's optimal risky portfolio share, which has been commonly regarded as rule of thumb in the Wall Street. He proposes that the investors should hold the risky portfolio share which is equals to "100 minus the investor's age" (Malkiel, 1999, p418). In other words, in the real financial world, the optimal risky portfolio shares are suggested to decline with age, which implies a downward sloping pattern for "the age–portfolio profile" (Canner *et al.,* 1997, cited in Iwaisako, 2009).

As been mentioned above, Merton (1969) predicted wealth has no impact on the optimal risky portfolio share under certain assumptions. However, research has generally revealed a positive correlation between the proportion of wealth invested in risky assets and households' wealth (Wachter and Yogo, 2010). Guiso *et al.* (2002, Table I.7) has documented this fact for five countries, namely the US, the UK, Netherland, Germany and Italy, based on various household surveys, including the 1998 Survey of Consumer Finances for the US, the 1997-98 Financial Research Survey for the UK, the 1997 Center Saving Survey for Netherlands, the 1993 Income and Expenditure Survey for Germany, the 1998 Survey of Household Income and Wealth for Italy. A similar correlation has also been found in early household surveys, for example, for the US, the 1962 and 1963 Federal Reserve Board Surveys of the Financial Characteristics of Consumers and Changes in Family Finances (Blume and Friend, 1975; Friend and Blume, 1975; cited in Wachter and Yogo, 2010, p3). In general, wealth does not only have an impact on the stock market participation but also the share of risky assets in a portfolio. The probability for the poor to invest in a risky asset is much smaller than the probability for the rich, and even conditional upon participation, the poor tend to invest less in risky assets. As also has been suggested in many empirical studies, after controlling for level of education and other demographic variables, wealth is still found to have positive effect on risky portfolio share (Wachter and Yogo, 2010).

2.3.3 Brief summary of the Merton model and its limitation

In conclusion, as we present on section 2.2.2, in Merton's model, an individual needs to decide his/her optimal consumption rule optimal portfolio allocation rule in a continuous time setting. The individual's objective is to maximize his/her expected value of discounted lifetime utility from consumption and discounted terminal wealth[6]. In particular, if we assume a two-asset model where a risk-free asset with "a constant rate of return" and a stochastically-risky asset with "a constant equity risk premium" (McCarthy, 2004, p10), an individual with CRRA or logarithmic utility function has the following optimal portfolio allocation rule: $\alpha_t^* = \frac{R-R^F}{\sigma^2\gamma} \equiv \alpha^*$. In other words, under the assumptions of constant investment opportunities and a utility function with CRRA, the optimal portfolio allocation rule is independent of his/her consumption choice, the investment time horizon or age and the investor's wealth (Merton, 1969). The representative agent invests a constant proportion of wealth in risky asset over his/her life time.

However, the optimum consumption and portfolio rules in a continuous-time model cannot be solved completely unless "when asset prices satisfy the 'geometric' Brownian motion hypothesis and the individual's utility function is a member of the HARA family, the consumption-portfolio problem is completely solved" (Merton, 1971, p394). Hence, this lack of a closed-form solution to the Merton model is one limitation. In addition, as we discuss in section 2.3.2, the classical Merton model not only fails to explain the relatively low risky portfolio share of the investors, but also fail to explain why older individuals have a higher risky portfolio share. Due to the huge mismatch

[6]The terminal wealth can be zero which means there is no bequest. The standard optimal portfolio allocation rule is still valid in this scenario.

between the empirical observations of the asset allocation and the prediction of the model under certain assumptions, the Merton model has not been widely applied and regarded as “a usable empirical paradigm” (Campbell *et al.,* 2003, p42).

2.4 Consumption/Portfolio model with time varying labour income (Carroll, 2011)

In this section, we look at a Consumption/Portfolio model with time varying labour income. We hope to see that introducing labour income risk into the model could explain the empirical observations of low stock market participation rates and low levels of risky assets shares. We set up the model following Carroll’s (2011) approach, and present the simulation results in section 2.4.3.

2.4.1 The model and the assumptions

The representative agent’s objective is to maximize his/her expected value of discounted lifetime utility from consumption:

$$\max E_t \sum_{t=0}^{T} \beta^t \; u(C_t)$$

subject to the following dynamic budget constraints:

$A_t = M_t - C_t,$

$Y_{t+1} = P_{t+1}\theta_{t+1}$[7]

$$M_{t+1} = A_t R^o_{t+1} + Y_{t+1}$$

where

β : subjective discount factor

$U(C_t)$: utility of consumption at time t

A_t: financial assets at time t

M_t: “cash on hand” at time t

C_t: level of consumption at time t

Y_{t+1}: labour income at time t

P_{t+1}: permanent labour income at time t+1

R^o_{t+1}: overall gross return on the representative agent’s asset portfolio between time t and t+1

Assumption 1: *Only two assets are available in the market, namely, a risk-free asset and a risky asset. The gross return on the risk-free asset is constant overtime and is denoted as R^F . The gross return on the risky asset between time t and t+1 is denoted as R_{t+1}, which is assumed to be log-normally distributed. The representative agent can choose to invest in these two assets and the proportion of the portfolio invested in the*

[7] The property of θ is presented in Assumption 3 on the next page.

risky asset between time t and t+1 is denoted as α_t. Hence, the overall gross return on the representative agent's asset portfolio between time t and t+1 is as follows:

$$R^o_{t+1} = R^F(1-\alpha_t) + R_{t+1}\alpha_t$$

Since we assume short sales are not allowed in the model, α_t should satisfy the following condition:

$$0 \leq \alpha_t \leq 1$$

Assumption 2: *we assume the average permanent labour income grows at rate φ_{t+1} from time t to time t+1, so $P_{t+1} = P_t\,\varphi_{t+1}$*

Assumption 3: *we assume θ is log-normally distributed, log $\theta \sim N(-\sigma^2_\theta/2, \sigma^2_\theta)$. This assumption ensures log $E(\theta)=0$, and hence $E(\theta)=1$. In other words, the expected value of the transitory labour income shock is 1.*

Assumption 4: *we assume the representative agent in our model has a utility function with CRRA, $U(C)=C^{1-\gamma}/(1-\gamma)$, where γ refers to coefficient of relative risk aversion.*

Now, we rewrite the model in terms of a Bellman equation as follows:

$$V_t(M_t, P_t) = \max_{\{C_t, \alpha_t\}}\{u(C_t) + \beta E_t[V_{t+1}(M_{t+1}, P_{t+1}]\}$$

subject to all the dynamic budget constraints listed above.

2.4.2 Normalization

In this section, we will use the permanent labour income P_t to normalize variables in order to reduce the number of state variables in the above value function. If we define $m_t = M_t / P_t$, and the representative agent consumes everything at the last period time T to maximize utility, then $V_T(M_T, P_T) = \frac{M_T^{1-\gamma}}{1-\gamma} = P_T^{1-\gamma} \frac{m_T^{1-\gamma}}{1-\gamma} = P_T^{1-\gamma} v_T(m_T)$.

If we define $c_t = C_t / P_t$, and c_t^* is the optimal ratio of consumption to permanent income, then we can derive

$$V_{T-1}(M_{T-1}, P_{T-1}) = u(C_{T-1}^*) + \beta E_{T-1}[V_T(M_T, P_T)]$$

$$= \frac{(C_{T-1}^*)^{1-\gamma}}{1-\gamma} + \beta E_{T-1}[P_T^{1-\gamma} \frac{m_T^{1-\gamma}}{1-\gamma}]$$

$$= P_{T-1}^{1-\gamma} \frac{(c_{T-1}^*)^{1-\gamma}}{1-\gamma} + \beta (P_{T-1}^{1-\gamma} \varphi_T^{1-\gamma}) E_{T-1}(\frac{m_T^{1-\gamma}}{1-\gamma})$$

$$= P_{T-1}^{1-\gamma} u(c_{T-1}^*) + P_{T-1}^{1-\gamma} \beta \varphi_T^{1-\gamma} E_{T-1}[v_T(m_T)]$$

$$= P_{T-1}^{1-\gamma} \{ u(c_{T-1}^*) + \beta \varphi_T^{1-\gamma} E_{T-1}[v_T(m_T)]\}$$

If we define

$$v_t(m_t) = \max_{\{c_t, \alpha_t\}} \{u(c_t) + \beta \varphi_T^{1-\gamma} E_t[v_{t+1}(m_{t+1})]\}$$

Then

$$V_{T-1}(M_{T-1}, P_{T-1}) = P_{T-1}^{1-\gamma} v_{T-1}(m_{T-1}).$$

Analogously, we can derive:

$V_{T-2}(M_{T-2}, P_{T-2}) = P_{T-2}^{1-\gamma} v_{T-2}(m_{T-2})$.

Hence, we can rewrite the previous Bellman equation and the maximization problem is reduced to one state variable as follows:

$$v_t(m_t) = \max_{\{c_t, \boldsymbol{\alpha_t}\}} \{u(c_t) + \beta \varphi_T^{1-\gamma} E_t[v_{t+1}(m_{t+1})]\}$$

subject to:

$$R_{t+1}^o = R^F(1-\alpha_t) + R_{t+1}\alpha_t$$

$$m_{t+1} = (m_t - c_t)\frac{R_{t+1}^o}{\varphi_{t+1}} + \theta_{t+1} [8]$$

$$0 \leq \alpha_t \leq 1$$

2.4.3 Simulation

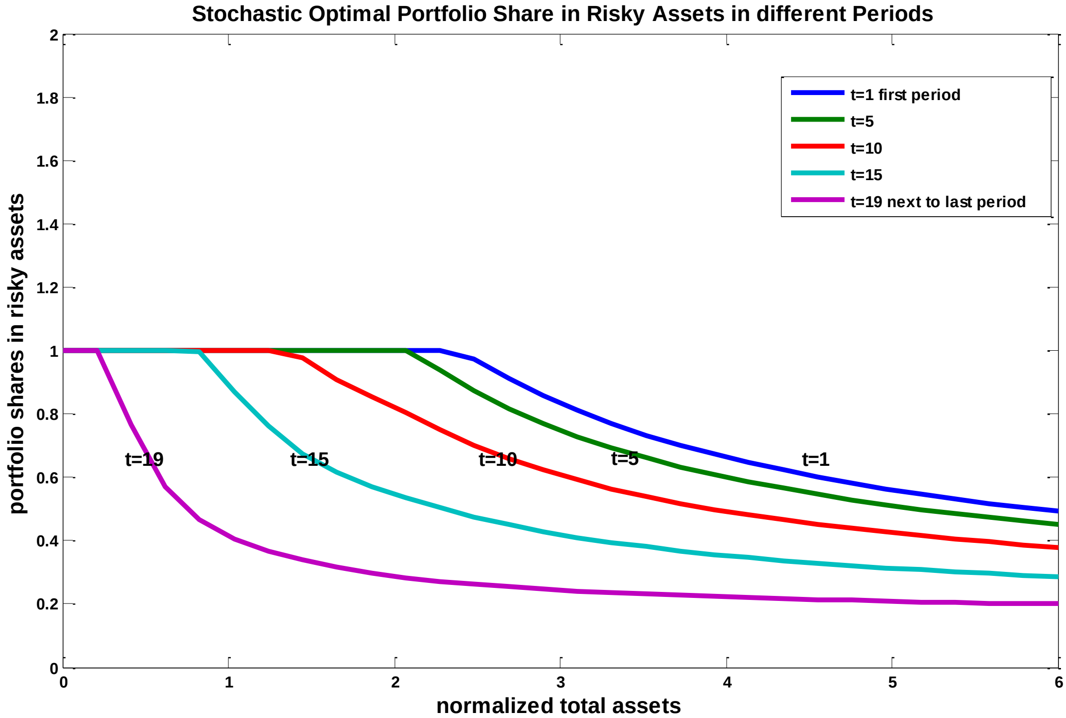
Since there is no analytical solution to this consumption/portfolio model, we will solve the optimization problem numerically using dynamic programming methods. We apply the code developed by Carroll (2011) and for the details about the numerical methods please refer to Carroll's paper (2011). Basically, we start from the last period and solve the model recursively backward. In the last period, the policy function is not important, because the individual consumes all his wealth and his/her value function is $V_T(M_T, P_T) = \frac{M_T^{1-\gamma}}{1-\gamma} = P_T^{1-\gamma} v_T(m_T)$, as in section 2.4.2. For each period before the last period, a grid search method is used to find the optimal risky asset share and the optimal

[8] Because $m_{t+1} = \frac{M_{t+1}}{P_{t+1}} = \frac{(M_t - C_t)R_{t+1}^o + Y_{t+1}}{P_{t+1}} = \frac{P_t(M_t - C_t)R_{t+1}^o}{P_t P_{t+1}} + \frac{Y_{t+1}}{P_{t+1}} = (m_t - c_t)\frac{P_t}{P_{t+1}} R_{t+1}^o + \theta_{t+1} = (m_t - c_t)\frac{R_{t+1}^o}{\varphi_{t+1}} + \theta_{t+1}$

consumption which maximize the value function. Once the value function is obtained for time t, we can use it and "continue the backwards recursion to period t-1 and so on back to the beginning of life" (Carroll, 2011, p32).

In the following three figures, we let R^F=0.02, risk premium=0.04, annual standard deviation in equity return is 15% and the individual's lifetime has been equally divided into 20 periods. In Figure 2.1, the x-axis is the normalized total assets, a_t , where $a_t = A_t/P_t$ and P_t is permanent labour income. The y-axis is portfolio shares in risky assets, measured in percentage. γ =6 for all time periods. As we can see, the investment time horizon has a positive effect on risky asset share. Given the same level of financial wealth, a_t, if the investment time horizon is long, in other words, if the representative agent is at the early stage of his/her life, for example t=1or t=5, then in theory, the optimal risky asset share for him/her will be relatively high, compared with the case of a short investment time horizon. In addition, the model predicts that for the young it is optimal to invest all of his/her wealth in risky assets when his/her financial wealth is less than twice his/her annual permanent labour income. Whereas for the older person, it is optimal to invest all of his/her wealth in a risky asset when his/her financial wealth is less than or equal to his/her annual permanent labour income. Interestingly, as the ratio of financial wealth to permanent labour income increases, the representative agent is more willing to hold less proportion of wealth in risky assets. Figure 2.1 shows that the poor who have a low ratio of financial wealth to labour income need to invest all of his/her wealth in risky assets, while the rich who have a high ratio of financial wealth to labour income should hold much less. Carroll (2011, p37) provides an explanation to this "bizarre prediction". In the model labour income risk is assumed to be uncorrelated with risk in stock market returns, so future consumption of the poor, mainly financed by future labour income, will be less correlated with future stock market returns. Hence, the poor will be more willing to hold a portfolio heavily tilted toward a risky asset. In contrast, future consumption of the rich, mainly financed by the financial wealth, will be highly correlated with stock market returns. Hence for the rich there will be a tilt in the portfolio toward the risk-free asset.

Figure 2. 1:Stochastic Optimal Portfolio Share in Risky Assets in Different Periods



The following two figures are used to illustrate the impact of risk aversion on households' risky asset shares. As we can see in Figure 2.2, if we keep the normalized total asset constant and set it equals to 2.5 (ie the ratio of financial wealth to permanent labour income is 2.5), the higher is the degree of risk aversion, the lower is the optimal portfolio share in risky assets, which is consistent with the empirical observations.

Figure 2. 2: Dynamic Stochastic Optimal Portfolio Share in Risky Assets for Different γ When Normalized Total Assets=2.5

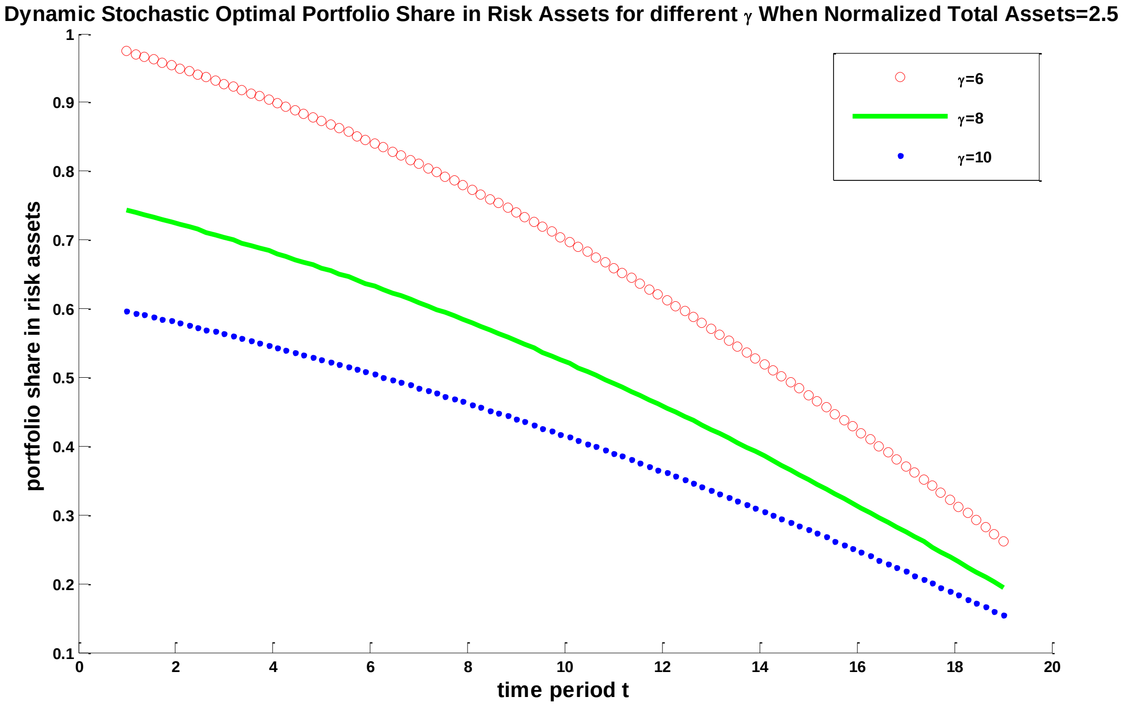
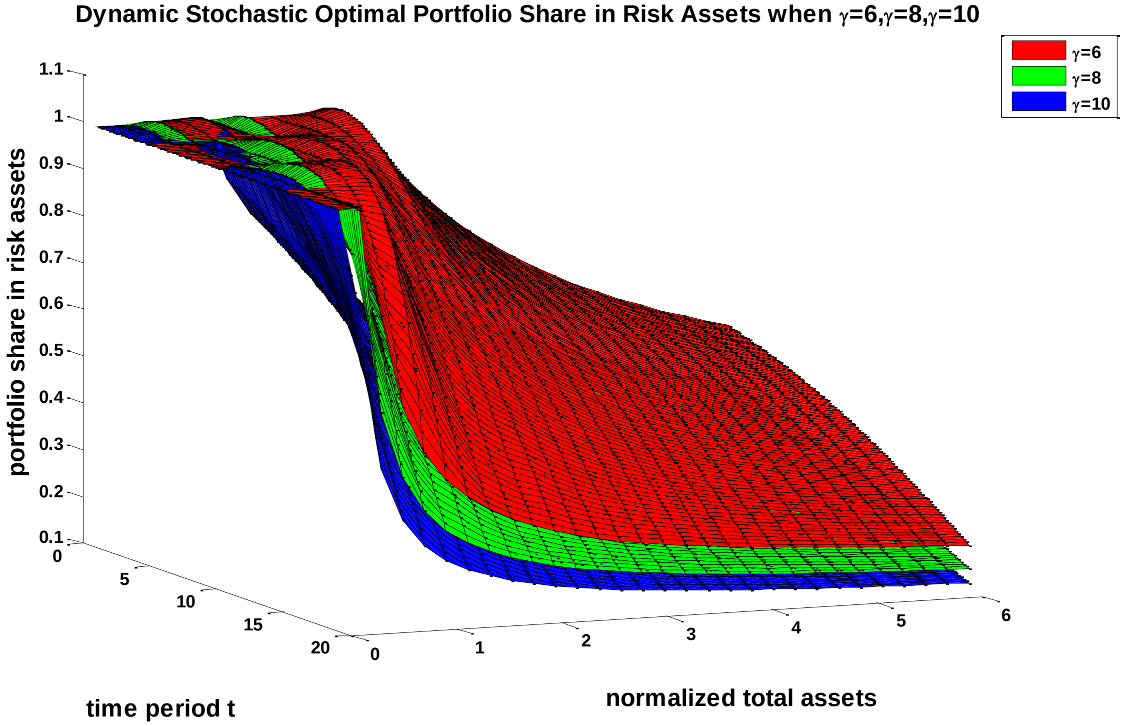


Figure 2.3 is three dimensional diagram which shows how households' risky asset share evolve due to the changes in investment horizon, the ratio of financial wealth to permanent labour income and the level of risk aversion. Similar to what we have found in Figure 2.1 and Figure 2.2, in Figure 2.3, we observe a high level of portfolio share in risky assets and also observe that the households' portfolio share in risky assets decreases as investment horizon shrinks; it decreases as the ratio of financial wealth to permanent labour income increases; it decreases if the household becomes more risk averse. However, in the real world, we observe relatively low level of portfolio share in risky assets and also observe that the households' portfolio share in risky assets increases as the investment horizon shrinks and/or the ratio of financial wealth to permanent labour income increases. Hence, this consumption/portfolio model with labour income risk is still not able to explain the empirical observations.

Figure 2. 3:Dynamic Stochastic Optimal Portfolio Share in Risky Assets when γ=6, γ=8, γ=10



2.5 strategic asset allocation

In conclusion, all the above models are found to contain propositions that are not empirically justified, predicting too high a proportion of risky assets in portfolios and failing to explain the age profile of the risky asset holding. Under restrictive assumptions, including constant relative risk aversion and constant investment opportunities, the risky asset allocation decision is independent of the investment time horizon, the investor's wealth and the investor's optimal consumption decision (Merton,1969). The predications from the consumption/ portfolio model with labour income risk also contradict empirical observations (Carroll, 2011; Bodie *et al*., 1992). However, if investment opportunities vary over time, multi-period investors will also be concerned about hedging consumption against shocks due to time-varying expected returns and/or covariances. As a consequence portfolio models, where consumption is the key driver of utility, are developed to handle the possibility of intertemporal hedging which arise naturally from time-varying returns (Campbell *et al.,* 2003; Chacko and Viceira, 2005). Such models are observed to describe what is called ''strategic asset allocation'' (Brennan *et al*., 1997, p1377). Cochrane (2007, p40) provided the optimal portfolio rule in a two-asset model which allows "mean returns, return volatility and labour income to vary overtime".

2.6 The consumption/portfolio models with habit formation

The portfolio allocation puzzle, which is commonly used to describe the puzzle that theoretical predication is contrary to the empirical observation, is "primarily a partial equilibrium manifestation of the equity premium puzzle" (Gupta, 2009, p2). Due to the relative success of habit formation models in solving "asset pricing puzzles"[9] and "aggregate consumption dynamics"[10] (Gomes and Michaelides, 2003, p731) in general equilibrium settings, habit formation has been introduced in households' portfolio allocation (partial equilibrium) models and the impact of habit formation has been examined in recent years. In the current literature, there are two forms of habit persistence in preferences for consumption, namely, external habit formation or "keeping up with the Joneses" type of habit in consumption, and internal habit formation, which depends on past consumption levels.

In section 2.6.1, we first look at a two-period model with a simple definition of internal habit formation in consumption. Later in section 2.6.2 we explore a continuous life-cycle model with a more realistic definition of internal habit formation.

[9] Please see Campbell and Cochrane (1999), Chan and Kogan (2002).
[10] Please see Carroll *et al.* (2000), Fuhrer (2000).

2.6.1 A two time period's consumption/portfolio model with internal habit formation

In this section we follow Lax's (2002) method and set up a two time period consumption/portfolio allocation model with internal habit formation. The habit level in time period (*t*) is a fixed proportion of consumption consumed in the last period (*t-1*). This assumption of habit level is made for simplicity and it generates a time-varying internal habit level in each time period. We find that even this simple model with habit formation can help partially to explain the empirical observations of low levels of risky assets shares.

In this discrete time framework we will continue to look at the two-asset case. We assume the risk-free asset has a constant gross return, R^F, and the gross return on the risky asset is *i.i.d.* lognormally distributed where $\log R_t \sim N(\mu, \sigma^2)$. Again, since we assume R^F, μ and σ are constant overtime, investment opportunities are constant overtime in this model.

In order to derive an explicit solution to the optimal portfolio problem, a power utility function is assumed again in the model. The objective function is as follows:

$$\max_{\{C_t, C_{t+1}, \alpha_t\}} E_t\left[\frac{(C_t - hC_{t-1})^{1-\gamma}}{1-\gamma} + \beta \frac{(C_{t+1} - hC_t)^{1-\gamma}}{1-\gamma}\right]$$

subject to $W_{t+1} = (W_t - C_t)[R^F(1-\alpha_t) + R_t\alpha_t]$

The habit level, *H*, in next time period *t+1* is a fixed proportion of consumption consumed in the current period t: $H_{t+1} = hC_t$ where $0 < h < R^F$. Similarly, we can get $H_t = hC_{t-1}$ where $0 < h < R^F$. The parameter h determines the extent to which habit in consumption persists. The parameter γ measures the curvature of the utility function. When h=0, γ represents the individual's relative risk aversion. When h>0, the relative risk aversion equals to $\frac{\gamma C}{C-H}$, which suggests that the risk aversion is "a state-dependent multiple of γ" (Lax, p12). Lastly, the parameter β is the subjective discount factor in this two-period model.

In addition, we have the following constraints:

$C_t > 0;\ W_t > 0; C_t > H_t;\ C_{t+1} > 0;\ W_{t+1} > 0; C_{t+1} > H_{t+1};\ \beta > 0; \gamma > 0;$

and short sale is not allowed in this model:

$0 \le \alpha_t \le 1.$

If we assume the individual will consume all of his wealth at time period *t+1*, then we can write out the value function:

$$V_t(W_t, H_t) = \max_{\{admissible\ C_t, \boldsymbol{\alpha_t}\}} \frac{(C_t - H_t)^{1-\gamma}}{1-\gamma} + \beta E_t\{\frac{[(W_t - C_t)(R^F(1-\alpha_t) + R_{t+1}\alpha_t) - H_{t+1}]^{1-\gamma}}{1-\gamma}\} \qquad (7)$$

In order to make sure admissible C_t, C_{t+1}, α_t exist and to make sure $C_t > H_t$, $C_{t+1} > H_{t+1}$, the ratio of wealth to habit level at time t, should satisfy:

$Z_t = \frac{W_t}{H_t} > 1 + \frac{h}{R^F} \equiv \underline{Z_t}.$

The reason is that at current time *t*, the individual needs to invest amount of wealth which equals to the present value of the future habit levels, PV_t(*FHL*), in the -free asset, so that he/she can maintain his/her standard living in the remaining time periods. Since this is a two- period model, so the present value of the future habit levels, PV_t(*FHL*), equals to:

$PV_t(FHL) = \frac{H_{t+1}}{R^F} = \frac{hC_t}{R^F}$.

If the individual invests an amount of wealth less than $\frac{hC_t}{R^F}$ in the risk-free asset, then there is a strictly positive probability he/she will not be able to consume at the habit level and will have a negative infinity in his/her expected utility.

Therefore, the requirement for the individual's current wealth to be able to finance the current habit level and the discounted future habit level is that:

$$W_t \geq H_t + PV_t(FHL) = hC_{t-1} + \frac{hC_t}{R^F} \geq hC_{t-1} + \frac{hH_t}{R^F} = hC_{t-1} + \frac{h^2 C_{t-1}}{R^F}.$$

Rearrange and we get:

$\frac{W_t}{H_t} \geq 1 + \frac{h}{R^F} \equiv \underline{Z_t}$ (the constraint on the ratio of wealth to habit level)

Now we will solve the optimization problem under all the assumptions and constraints we listed above. The optimization problem is as follows:

$$\max_{\{admissible\ C_t, \boldsymbol{\alpha_t}\}} \frac{(C_t - H_t)^{1-\gamma}}{1-\gamma} + \beta E_t \{\frac{[(W_t - C_t)(R^F(1-\alpha_t) + R_{t+1}\alpha_t) - H_{t+1}]^{1-\gamma}}{1-\gamma}\}$$

or

$$0 = \max_{\{C, \boldsymbol{\alpha}\}} f(\mathrm{C}, \alpha; \mathrm{W}; \mathrm{H}; \mathrm{t}).$$

Hence we can write out the optimality conditions in the form:

$$\begin{cases} \mathrm{f}(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \mathrm{f}_\mathrm{C}(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \mathrm{f}_\alpha(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \text{subject to all the contraints} \end{cases}$$

We know $f(C^*, \alpha^*; W; H; t) = 0$, now we take the partial derivative of $f(C, \alpha; W; H; t)$with respect to *C* and with respect to α respectively and set them equal to zero:

$$(C_t - H_t)^{-\gamma} = \beta E_t\{[(W_t - C_t)(R^F(1-\alpha_t) + R_{t+1}\alpha_t) - hC_t]^{-\gamma}[R^F(1-\alpha_t) + R_{t+1}\alpha_t + h]\} \quad (8)$$

$$E_t\{[(W_t - C_t)(R^F(1-\alpha_t) + R_{t+1}\alpha_t) - H_{t+1}]^{-\gamma}(R_{t+1} - R^F)\} = 0$$

The first-order condition (8) implies that the optimal consumption is achieved when the marginal utility of consumption equals the marginal utility of wealth. The left-hand side refers to the marginal utility of consumption by consuming one extra unit of goods, which equals $(C_t - H_t)^{-\gamma}$. The right hand side refers to marginal utility of wealth by increasing one extra unit of wealth.

The optimal portfolio allocation at current time *t* in this two-asset and two-period case is as follows:

$$\alpha_t^* = \bar{\alpha}(1 - \frac{h{C_t}^*}{R^F(W_t - {C_t}^*)}) \quad (9)$$

where ${C_t}^*$ is the optimal consumption and $\bar{\alpha}$ is the optimal risky asset share without habit formation and it is a solution to the following equation:

$$E[(R^F(1-\bar{\alpha}) + R_{t+1}\bar{\alpha})^{-\gamma}(R_{t+1} - R^F)] = 0$$

The optimal consumption at current time *t* is:

$${C_t}^* = \frac{\delta_t}{1 + \left(1 + \frac{h}{R^F}\right)\delta_t} W_t + \frac{1}{1 + \left(1 + \frac{h}{R^F}\right)\delta_t} hC_{t-1},$$

where $\delta_t = (\beta\left(1+\frac{h}{R^F}\right)\varphi)^{-\frac{1}{\gamma}}$

and $\varphi = E_t[(R^F(1-\bar{\alpha}) + R_{t+1}\bar{\alpha})^{1-\gamma}]$

As we can see, the optimal risky asset allocation (9) has two parts. The first part, $\bar{\alpha}$, is the standard myopic mean-variance portfolio, and the second part is attributed to the habit formation in consumption. The value of the second part depends on "how close the wealth at time *t+1* is to the minimum level of wealth required to sustain habit at time *t+1*" and it is "always less than 1" (Gupta, 2009, p17).

This suggests that even in this simplest two-period case the individual with habit formation in preferences will hold a more conservative portfolio than the individual without habit in preferences. In other words, introducing habit formation into the portfolio allocation model helps to explain the empirical observations where households are found to invest a relatively low proportion of wealth in risky assets.

2.6.2 Discrete life cycle model with internal habit formation (Lax, 2002)

If we extend our two-period model to a discrete life-cycle model and keep all the assumptions the same, then the optimal consumption rule [11]and risky asset allocation rule is as follows (Lax, 2002):

$C_t^* = A_t W_t + B_t C_{t-1}$,

and

[11] Please see Lax (2001) for details on the optimal consumption rules.

$$\alpha_t^* = \bar{\alpha}(1 - \frac{\frac{hC_t^*}{R^F - h}(1 - \left(\frac{h}{R^F}\right)^{T-t})}{W_t - C_t^*})$$

where $0 \leq t \leq T$ (10)

Now if we assume time t and time s, where $t>s$. For time t and time s, the individual has the same level of wealth, $W_t = W_s$, and he/she has the same level of optimal consumption, $C_t^* = C_s^*$. Then based on equation (10),we can get $\alpha_t^* > \alpha_s^*$. This suggests that in a portfolio allocation problem with habit formation in preferences, the older individuals are supposed to have a higher proportion of wealth invested in risky assets than the younger individuals are supposed while the elder and the younger have the same level of wealth and choose the same optimal consumption level. This finding is similar to the one suggested in Gupta's (2009) portfolio allocation model, which has a more realistic definition for internal habit formation and it is a continuous time model. We will discuss it in the next section.

2.6.3 Continuous life-cycle model with internal habit formation (Gupta, 2009)

Now we will look at a life-cycle consumption/portfolio allocation model with a more realistic definition of internal habit formation. The habit level is a weighted average of previous consumption and the level of consumption consumed today will have a positive impact on the future habit levels and hence on the future utilities. Therefore, the individual will not consume excessively today because he knows such behaviour will lead to a big increase in his/her standard of living in the following time periods. In order to ensure the individual's future consumption level is at or above the habit level, the individual with habit in preferences needs to hold a relatively conservative portfolio compared with an individual without habit in preferences. The relatively conservative portfolio could finance the individual to maintain his/her standard of living when the stock market goes down (Gupta, 2009).

We have a continuous time framework and continue to study the two-asset case. We assume the risk-free asset has a gross return, R^F, for an infinitesimal time period dt, and the return on the risky asset follows Brownian motion and equals $\mu dt + \sigma dB(t)$ where μ is average return on this risky asset, σ is the standard deviation of the risky asset's return, and $dB(t)$ denotes a Brownian motion. Since we assume R^F, μ and σ are constant overtime, so investment opportunities are constant overtime in this model.

In order to derive an explicit solution to the optimal portfolio problem, a power utility function is assumed in the model. The objective function is as follows:

$$\max_{\{C_s,\alpha_s\}} E_t\left[\int_t^T e^{-\delta s}\frac{(C_s - H_s)^{1-\gamma}}{1-\gamma}ds\right.$$

where, γ, the coefficient of relative risk aversion, is set to be greater than 1. When γ is close to 1, the "period utility function can be approximated by the natural logarithm" (Gupta, 2009).

The habit level, H, is a weighted average of previous consumptions:

$$H_t = e^{-at}H_0 + b\int_0^t e^{a(s-t)}C_s ds \;,$$

where parameter *a* and parameter *b* determines "how much past habit is discounted" and " how much current consumption affects current habit" respectively (Gupta, 2009,p10).

The following process describes how the habit level evolves:

$$dH_t = (-aH_t + bC_t)dt$$

On the right-hand side, the first part represents an instantaneous discounted value of the habit level, and the second part represents the change in habit level attributed to current consumption.

The wealth of the individual is defined as follows:

$$W_t = e^{R^F t}W_0 + \int_0^t e^{R^F(s-t)}\{[R^F + \alpha_s(\mu - R^F)]W_s - C_s\}ds,$$

and the budget constraint is:

$$dW_t = \{[R^F + \alpha_t(\mu - R^F)]W_t - C_t\}dt + \alpha_t\sigma W_t dB_t \; ,$$

which is similar to the budget constraint in Merton (1969) as we discuss above in section 2.2.2.1. On the right-hand side of the equation, the first part is a deterministic term and the second part is a stochastic term. The stochastic term is generated by the volatility of the return on the risky asset and it follows a Brownian motion process.

In addition, we have the following constraints:

$C_t > 0;\ W_t > 0; C_t > H_t;$

and short sale is not allowed in this model:

$0 \leq \alpha_t \leq 1.$

Now, we will write out the value function:

$$V_t(W_t, H_t) = \max_{\{admissible\ C_s,\boldsymbol{\alpha_s}\}} E_t\left[\int_t^T e^{-\delta(s-t)} \frac{(C_s - H_s)^{1-\gamma}}{1-\gamma} ds\right.$$

In order to make sure admissible C_s and α_s exist for all $t \le s \le T$ and $C_s > H_s$ for all $t \le s \le T$, the ratio of wealth to habit level at time t, where $0 \le t \le T$, should satisfy:

$$Z_t = \frac{W_t}{H_t} > \frac{1}{R^F + a - b}[1 - e^{-(R^F + a - b)(T-t)}] \equiv \underline{Z_t}.$$

As we can see that $\underline{Z_t}$ will decrease as t increases, so this time variation will generate the life-cycle or age effect on portfolio allocation and the optimal risky asset allocation will depend on the difference between the ratio of wealth to habit level and the lower bound of this ratio, in other words, the difference between Z_t and $\underline{Z_t}$.

Furthermore, we need to assume $R^F + a - b > 0$, so that $\underline{Z_t}$ will be greater than 0, and also assume $0 \le \frac{\mu - R^F}{\gamma\sigma^2} \le 1$, so that the optimal risky asset allocation satisfies: $0 \le \alpha_t \le 1$.

Now we will solve the optimization problem under all the constraints we listed above.

We first write out the Hamilton-Bellman-Jacobi (HBJ) equation which the value function must satisfy:

$$0 = \max_{\{C,\boldsymbol{\alpha}\}} e^{-\delta t}\frac{(C-H)^{1-\gamma}}{1-\gamma} + \frac{\partial V(W_t,H_t)}{\partial t} + \frac{\partial V(W_t,H_t)}{\partial W}\{[R^F + \alpha(\mu - R^F)]W - C\}$$

$$+\frac{1}{2!}\frac{\partial^2 V(W_t,H_t)}{\partial W^2}(\alpha\sigma W)^2 + \frac{\partial V(W_t,H_t)}{\partial H})(-aH + bC)$$

so if we define

$$f(C,\alpha;W;H;t) = \max_{\{C,\boldsymbol{\alpha}\}} e^{-\delta t}\frac{(C-H)^{1-\gamma}}{1-\gamma} + \frac{\partial V(W_t,H_t)}{\partial t} + \frac{\partial V(W_t,H_t)}{\partial W}\{[R^F + \alpha(\mu - R^F)]W - C\}$$

$+\frac{1}{2!}\frac{\partial^2 V(W_t,H_t)}{\partial W^2}(\alpha\sigma W)^2 + \frac{\partial V(W_t,H_t)}{\partial H})(-aH + bC)$, then the HBJ equation becomes as follows:

$0 = \max_{\{C,\alpha\}} f(\mathrm{C}, \alpha; \mathrm{W}; \mathrm{H}; \mathrm{t})$.

Hence we can write out the optimality conditions in the form:

$$\begin{cases} \mathrm{f}(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \mathrm{f_C}(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \mathrm{f}_\alpha(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0 \\ \text{subject to all the contraints} \end{cases}$$

We know $\mathrm{f}(\mathrm{C}^*, \alpha^*; \mathrm{W}; \mathrm{H}; \mathrm{t}) = 0$, which is the HBJ equation, now we take the partial derivative of $\mathrm{f}(\mathrm{C}, \alpha; \mathrm{W}; \mathrm{H}; \mathrm{t})$with respect to C and with respect to α respectively and set them equal to zero:

$$e^{-\delta t}(C-H)^{-\gamma} - \frac{\partial V(W_t,H_t)}{\partial W} + b\frac{\partial V(W_t,H_t)}{\partial H} = 0$$

$$\frac{\partial V(W_t,H_t)}{\partial W}(\mu - \mathrm{R^F})\mathrm{W} + \frac{\partial^2 V(W_t,H_t)}{\partial W^2}\alpha\sigma^2 W^2 = 0$$

If we rearrange the first equation which is the first-order condition for consumption, then we obtain the following equation:

$$e^{-\delta t}(C-H)^{-\gamma} + b\frac{\partial V(W_t,H_t)}{\partial H} = \frac{\partial V(W_t,H_t)}{\partial W}$$

This rearranged condition implies that the optimal consumption is achieved when the total marginal utility of consumption equals the marginal utility of wealth. Since we have habit formation in this case, the total marginal utility of consumption consists of two parts. The first part refers to the marginal utility of consumption by consuming one extra unit of goods, which equals $e^{-\delta t}(C-H)^{-\gamma}$. The other part refers to disutility which is equal to $\frac{\partial V(W_t,H_t)}{\partial H}$. The reason why we name it disutility is because consuming one extra unit of goods will increase the habit level, hence reduces the utility.

The first-order condition for the risky asset allocation implies that “the proportion of wealth invested in risky assets depends on the curvature of the value function, which is the elasticity of marginal utility with respect to wealth” (Gupta, 2009, p13).

The optimal portfolio allocation rule[12] in this two-asset case has been presented by Gupta (2009) as follows:

$$\alpha_t^* = \frac{\mu - R^F}{\sigma^2 \gamma}\left(1 - \frac{H\underline{\underline{Z}}_t}{W}\right) \tag{11}$$

The optimal risky asset allocation rule has two parts. The first part, $\frac{\mu - R^F}{\sigma^2 \gamma}$, is the standard myopic mean-variance portfolio, and the second part is attributed to the habit formation in consumption. The value of the second part depends on “how close wealth is to the minimum level of wealth required to sustain habit” and it is “always less than 1” (Gupta, 2009, p17).

This suggests that the individual with habit formation in preferences will hold a more conservative portfolio than the individual without habit in preferences. Hence, introducing habit formation into the portfolio allocation model helps to explain the empirical observations where households are found to invest a relatively low proportion of wealth in risky assets.

[12] For details about the optimal consumption rules, please see Gupta (2009, p15) .

Now if we assume time t and time s, where t>s. For time t and time s, the individual has the same level of wealth, W(t)=W(s), and he/she has the same level of habit, H(t)=H(s).

Then based on equation (12): $\frac{1}{R^F+a-b}[1-e^{-(R^F+a-b)(T-t)}] \equiv \underline{Z_t}$ where $0 \leq t \leq T$,

we can infer that $\underline{Z_t}$<$\underline{Z_s}$. Hence, equation (11), $\alpha_t^* = \frac{\mu-R^F}{\sigma^2\gamma}(1-\frac{H\underline{Z_t}}{W})$, implies that $\alpha_t^* > \alpha_s^*$.

This leads to another finding which could be regarded as an important contribution by introducing habit formation in preferences into the portfolio allocation problem. During the life cycle, the level of individual's risk aversion will vary and it "depends on how much wealth individuals have in excess of the minimum required level of wealth to sustain habits in the future" (Gupta, p39). If current wealth is close to the minimum level of wealth required to sustain habit in the future, the individual will be more risk averse. Compared with younger individuals, the older individuals have shorter time horizon for which they need to maintain their standard of living. In other words, the minimum required level of wealth to sustain habits in the future is less for the older individuals than for the younger individuals. Therefore, if we assume older individuals have same current level of wealth as the younger individuals, the older individuals' current level of wealth is not that close to minimum level of wealth required to sustain habits in the future. This means the older individuals are less risk averse than the younger individuals. The older individuals are less concerned about sustaining their habits in the future and they don't need to invest a higher proportion of wealth in risk-free assets which can provide finance for maintaining their consumption habit. Hence, in order to maximize utility over the lifecycle, the older individuals are supposed to invest a higher proportion of wealth in risky assets than the younger individuals are supposed to. This finding is consistent with the empirical observations.

2.6.4 Current literature on examining the habit formation effect on portfolio choices

Table 2.2 provides a summary of the recent literature which studies the optimal consumption/portfolio model with habit in consumption. As we can see, except Gomes and Michaelides (2003), other authors (Munk, 2008; Polkovnichenko, 2007; Gupta, 2009) found introducing habit into the model can help to explain the empirical observations, for example, the younger should hold more conservative portfolios, compared with the older.

Table2. 2: a summary on recent literature which study the optimal consumption/portfolio model with habit in consumption

Authors	Methodology	Findings	Journal	Habit
Gomes and Michaelides (2003)	introduce internal habit formation preferences in a life-cycle portfolio choice model with uninsurable labour income risk and stock market participation costs (in a finite horizon discrete time settings).	They find that introducing habit formation preferences in a life-cycle asset allocation model could not explain the empirical observations. With habit, individuals start to save early in life in order to smooth consumption over a long period of time and are more willing to pay the stock market participation cost. Imposing small or modest value of risk aversion, nearly all of their wealth will be invested in risky assets.	*Review of Economic Dynamics*	Both ratio and additive internal habit preferences are considered.

Polkovnichenko (2007)	work on additive and internal habit formation preferences in a life-cycle model with stochastic uninsurable labour income risk (in a finite horizon discrete time settings).	With habit formation, the younger will hold more conservative portfolio than the elder. "The effects of habits on portfolio choice are robust to income smoothing through borrowing or flexible labour supply" (Polkovnichenko,2007, p83).	*Review of Financial studies*	additive internal habit preferences is considered
Munk (2008)	derive optimal consumption and investment policies for investors with habit persistence in preferences for consumption when the financial market provides time-varying investment opportunities, but is dynamically complete (in finite continous time settings).	With habit formation, individuals would like to invest in safe assets, such as bonds and cash, compared with other risky assets. The reason is that holding bonds and cash would leave households with a low probability of consumption falling close to habit level.	*Journal of economic dynamic and control*	additive internal habit preferences is considered

Gupta (2009)	Solve the optimal consumption and portfolio choice life cycle problem analytically in the context of for investors with internal habit formation in a continuous time finite horizon model.	He find with this additive and internal habit formation, the young households will hold less risky portfolios compared with the middle-aged households, because the young households need to maintain their consumption level above habit for a longer horizon, whereas the older households have shorter time horizon.	*PhD thesis*	additive and internal habit formation

2.7 Recent development on theoretical explanations for portfolio behaviour

In recent years, much effort has gone into exploring the potential of Merton's portfolio allocation theory. They took different approaches. Some of the economists solved Merton's problem by introducing certain assumptions. For example, by assuming mean reverting asset returns and a complete market, Wachter (2002) solved the problem in a closed form if the investor had a power utility function over terminal wealth or consumption. Some of them, like Campbell and Viceira (2001, 2002), they derived an approximate analytical solution by assuming the investor had Epstein and Zin preference and setting intertemporal elasticity of substitution equal to one. Other academics solved the problem numerically by taking advantage of development in computer technology and dynamic programming, such as Balduzzi and Lynch (1999), Barberis (2000), Brennan *et al*. (1997), Cocco *et al*. (2005), and Lynch (2001) (cited in Campbell *et al.,* 2003, p43).

Meanwhile, during this recent development, a number of factors, which are likely to influence portfolio selection, have been analysed theoretically. Among them we note transactions costs and borrowing constraints (Constantinides, 1986; Davis and Norman, 1990; Heaton and Lucas,1997), life-cycle considerations (Gomes and Michaelides, 2003; Polkovnichenko, 2007; Cocco *et al.,* 2005), taxation (Alan *et al*. 2010; Poterba and Samwick 2003) and the variation in background risk exposure from sources such as labour and entrepreneurial income or real estate holdings (Cocco *et al.,*2005; Viciera, 2001). As a consequence cross-sectional variation in asset allocation has been more fully explained, although differences between the theory and empirical observation still remains (Cauley *et al.,* 2007).

2.7.1 Theoretical consideration of housing effect

Does housing have an impact on households' asset allocation? Can housing be used to explain the cross-sectional variation in asset allocation? From a theoretical perspective, housing could affect households' asset allocation in three different ways, namely, the investment asset effect, the "consumption commitment" effect, and the housing wealth effect.

2.7.1.1 Negative investment asset effect

Housing, typically, is regarded as consumption good as well as an investment asset. Brueckner (1997) acknowledged this property of housing. When he examined the asset allocations of homeowners, he imposed an investment constraint in a mean-variance portfolio model. This constraint was introduced by Henderson and Ioannides (1983) and required that the quantity of housing investment should be equal to or larger than the quantity of housing consumption. Brueckner (1997) also assumed the homeowner can choose to invest in one risk-free asset and a number of risky assets in order to maximize his/her utility of housing consumption and non-housing consumption at the end of the period. After considering the vector of expected returns and the covariance matrix for housing and other assets, Brueckner (1997) derived analytical solutions to the portfolio choice model. He showed that under the investment constraint and other assumptions, "the homeowner's optimal portfolio is inefficient in a mean-variance sense"

(Brueckner, 1997, p159). The homeowner over invested in housing and under invested in risky assets.

Similar "crowding out" effects of housing on risky assets were found by Flavin and Yamashita (2002) who carried out mean-variance analysis. On the one hand, they considered housing as a consumption good, and households were allowed to mortgage and borrow up to the 100 percent of the house value. On the other hand, they treated housing as a risky investment asset and allowed the households to invest in housing as well as other risky assets. Without short selling in other risky assets and by using the data from the Panel Study of Income Dynamics (PSID), Flavin and Yamashita (2002) estimated a vector of expected returns and the covariance matrix for housing and other risky assets, solved the constrained efficient frontiers for different values of the households' ratio of housing to net worth, and determined the optimal portfolio numerically, given the addition information on degree of risk aversion.

They found that "the inclusion of housing has the effect of altering the risk and return trade-off in such a way that most households are at a corner with respect to T-bills" (Flavin and Yamashita, 2002, p346). This is consistent with the findings in Brueckner's (1997) paper that when the house price risk is taken into account, investment in housing would generate a negative impact on risky asset holdings. Flavin and Yamashita (2002) also found that the ratio of housing to net wealth had a large impact on households' asset allocation. Compared with young households, middle-aged households are normally less leveraged and will not have large holdings of housing relative to net worth. Hence, the risk facing by the middle aged households is relatively lower than the risk facing by the young households. In order to maximize utilities, the middle-aged households will be willing to take more risk by investing a higher proportion of their wealth in risky assets, whereas the young households will be willing to take less risk by either paying down their mortgage or investing in relatively less risky assets.

As we can see from above, Brueckner (1997) and Flavin and Yamashita (2002) explored the negative investment asset effect of housing on risky asset shares by setting up a mean-variance portfolio model. In comparison, Cocco (2005) also found a similar effect but by setting up a lifecycle portfolio model. In his model, the individual derived utility from housing consumption and non-durable goods, and there was a bequest motive. The fluctuations in house prices were assumed to be correlated with labour income shocks. He also assumed a minimum house size in the model and in each time period the individual was forced to move to another house with probability, π. There was transaction cost when the house sale took place and there was a maintenance costs in the model. Both transaction cost and maintenance costs were proportional to the house value. Since no analytical solution could be found, he solved the optimization problem numerically. He showed that "housing can reduce stock market participation rates from 76% to 33% in a calibrated life-cycle model" (Chetty and Szeidl, 2010, p1). Although Cocco (2005) did not state explicitly that this housing effect comes from three channels, namely, the investment asset aspect (or house price risk aspect), the "consumption commitments" aspect, and the housing wealth aspect, he did suggest that this housing effect comes from two sources. Firstly, house price risk can have a negative impact on stock market participation. Secondly, the minimum house size requirement forced the individual to invest in house and this housing investment kept individual's liquid assets at a relatively low level, so he/she chose not to participate in the stock market (Cocco, 2005, p555). The larger of the minimum house size, the lower was the stock market participation rate. As we can see in the next section 2.7.1.2, this second source of housing effect, suggested by Cocco (2005) actually can be classified as the negative "consumption commitments" effect. Notably, although Cocco (2005) did not mention the housing wealth effect, he did find older individuals hold a higher proportion of wealth in risky assets than younger individuals do. He explained this in the way that as individual ages, "liquid assets become less important relative to other asset holdings (human capital and housing) for future consumption" (Cocco, 2005, p552). Hence the individual is more willing to take risky position in asset holdings. This argument is similar to the housing wealth effect. Housing could act as a big financial security and create a motive for the individual to invest a higher proportion of wealth in risky assets. In other words, the individual will be less risk averse and be willing to invest in risky assets (ie take large-payoff gambles) if he/she has large wealth in housing and is facing a big negative wealth shock (Chetty and Szeidl, 2007). He/she knows he/she can downgrade to a smaller house and use the extra money to keep his/her habit in consumption and maintain the standard of living. We discuss this housing wealth effect in more detail in the following section 2.7.1.3.

2.7.1.2 Negative "consumption commitments" effect

Housing could also affect households' asset allocations by another channel, the "consumption commitments" effect. The consumption commitments normally come from some durable goods, such as house and vehicles, and services like insurance. These goods and services involve transaction costs and are not frequently adjusted (Chetty and Szeidl, 2007). The "consumption commitments" effect of housing was studied by Grossman and Laroque (1990). In their theoretical model, an individual needed to decide his/her optimal consumption rule and optimal portfolio allocation rule where the utility of consumption only comed from holding a durable good which was housing. When the house was sold, the individual was entitled to a transaction fee. The individual was allowed to invest in a risk-free asset and a number of risky financial assets. At each time, the individual needed to decide optimally whether he/she should change house or not and decided what the optimal proportions of remaining wealth he/she should invest in the risk-free and risky financial assets. Grossman and Laroque (1990, p25) suggested that the optimal consumption of housing was not “a smooth function of wealth”. In order to maximize utilities, the individual had to wait until his/her wealth increased significantly before he/she increased the consumption of housing; or he/she had to wait until his/her wealth dropped dramatically before he/she reduced the consumption of housing. This “consumption commitments” would lead the individual to be more risk averse and to invest a smaller proportion of wealth in risky asset than he/she would invest if there is no transaction cost and he/she was free to adjust housing continuously (Grossman and Laroque, 1990).

The impact of “consumption commitments” of housing on asset allocation was also studied by Fratantoni (2001). Compared with the model in Grossman and Laroque’ paper (1990), Fratantoni (2001) assumed during the individual’s life time, there was only one house that could be bought with mortgage and when he/she bought and sold the house there was no transaction cost. In his theoretical model, there were seven periods and each period contained ten years. The individual maximized his utility from nonhousing consumption and housing services over the finite horizon and no bequest was left. His “consumption commitments” of housing comed from the committed housing expenditure, both in renting periods and in house owner periods. He was assumed to rent a house in the first two periods, so that he could save enough money to make a down payment on a house at the end of the second period. Then from the third period to fifth periods, the individual needed to pay off his/her mortgage in fixed payments, and he/she also needed to pay for maintenance costs, which was proportional to the house size. During the sixth period, although there was no mortgage payment, he/she still needed to pay for maintenance costs. In the last period, he/she sold the house and became a renter again and consumed all the remaining wealth. Although analytical solution could not be found, based on simulation results, Fratantoni (2001) concluded that the individuals with a larger mortgage commitment invest a smaller proportion of wealth in risky assets after controlling for the labour income risk. This negative impact of housing "consumption commitments" on risky asset shares is consistent with the findings in previous research (eg: Grossman and Laroque, 1990).

We could also understand this negative housing "consumption commitments" effect by using the concept of habit in consumption. Remember that habit allows risk aversion to vary significantly, particularly for consumption levels close to the habit level, and hence with mortgage commitment, we expect lower participation rates and less risky assets shares.

2.7.1.3 Positive housing wealth effects or positive "consumption commitments" effects

The issue of how consumption commitments would have an impact on households' risk preferences was studied by Chetty and Szeidl (2007). They set up a theoretical model which assumed the individual needed to maximize his/her utility of consuming food and consuming housing services over a finite time period. The transaction cost or adjustment cost was proportion to the house value. And after characterizing "the risk preferences in an expected utility model with commitments", they found that the effect of "consumption commitments" on individual's level of risk aversion depended on the scale of the risk. Due to consumption commitments, the individual would become less risk averse if he/she faced a large shock and the individual would become more risk averse if he/she faced a small or moderate shock. The reason was that when the individual experienced a large negative shock, instead of cutting food expenditure dramatically to maintain the commitment in housing, he/she would be better off if he/she chose to pay an adjustment fee and moved to a smaller house. When the individual experienced a large positive shock, it would be optimal for him/her to pay an adjustment fee and moved to a large house rather than spending all the extra income on food consumption. In contrast, when the individual experienced a small shock, no matter if it was a negative one or positive one, "the utility gain from fully reoptimizing the consumption bundle was insufficient to offset the transaction cost", he/she should keep his/her housing consumption level unchanged and "there was an (S, s) band where the agent does not move" (Chetty and Szeidl, 2007, p844). In order to maximize utility, the individual had to cut his/her spending on food when facing a small negative shock and increased his/her spending on food when facing a small positive shock. Hence, Chetty and Szeidl (2007, p832) concluded that with consumption commitment in the model, the transaction cost in housing “amplify risk aversion” by forcing the individual to concentrate volatility in wealth on non-housing goods, such as food, when the individuals were facing small and moderate risks. Later 2010, Chetty and Szeidl (2010, p1) suggested that this “consumption commitment” effect can decrease the optimal risky asset share, However, they did not indicate that this negative impact of housing on risky asset share only occurred when the individual was facing small and moderate risks. When the individual was facing large risk, housing could be regarded as self-insurance and provided financial security to maintain the living standard, for example, maintaining the habit level of food consumption, if the individual moved to a smaller house or sold the house. This was why Chetty and Szeidl (2007, p831) suggested that with housing the individual became less risk averse and was willing to “take large-payoff gambles” when “the value function over wealth for the individual with commitment”… … is “at the edge of the (S,s) band”. From this perspective, we can see that housing could act as a big financial security and create a motive for the individual to invest a higher proportion of wealth in risky assets. This positive effect of housing on the risky asset share is named the housing wealth effect in this thesis.

2.7.1.4 The overall effect of housing on household asset allocation

In conclusion, we suggest that the overall effect of housing on household asset allocation is determined by three forces, namely, the investment asset effect, the “consumption commitment” effect, and the housing wealth effect. The investment asset effect and the “consumption commitment” effect of housing crowd out risky asset holdings, whereas the housing wealth effect provides financial security and increases individual's willingness to take a risky position in asset holdings.

2.7.2 The effect of transaction cost

Will a transaction cost have an impact on households' asset allocations? How well will the transaction costs explain the cross-sectional variation in asset allocation? Recent studies suggest that transaction costs can explain slow adjustment speed in the portfolio rebalancing process and, together with the life-cycle considerations, transaction costs "appear necessary to explain the lack of stock market participation" (Curcuru, 2004, p1).

2.7.2.1 Definition of transaction costs

The transactions costs have a broad definition. They do not only include tangible costs, such as brokerage fees, fixed and variable costs of trading in financial markets, information cost but also include intangible costs, such as the time costs of understanding financial markets, analysing the data and psychic cost of investing in risky assets (Curcuru, *et al*., 2004, p2; Dumas and Luciano, 1991, p577).

2.7.2.2 Explaining slow portfolio adjustment

There are a number of papers examining how transaction costs could have an impact on households' asset allocation decisions. Constantinides (1979, 1986) set up a consumption/portfolio choice model with proportional transaction cost in an infinite horizon framework. The household was assumed to maximize his/her discounted utility of consumption overtime. The risky asset allocation rule was a (S,s) type rule. If the ratio of risky asset holdings to risk free asset holdings was between the upper barrier, S, and the lower barrier, s, then no transactions was needed between the risky asset and the risk-free asset. If the ratio of risky asset holdings to risk-free asset holdings fell below barrier s, then the household needed to sell a small amount of a risk-free asset and buy a risky asset. If the ratio of risky asset holdings to risk-free asset holdings exceeded upper barrier S, then household needed to sell a small amount of risky asset and buy a risk-free asset. Constantinides (1986) also found that introducing proportional transaction cost into the model leaded to a lower trading frequency, which implied that "portfolio shares fluctuate more than in a frictionless environment" (Curcuru, *et al.*, 2004, p14).

Davis and Norman (1990) also studied optimal consumption/portfolio choices with proportional transactions costs and they showed that the optimal portfolio allocation under transaction costs was an interval as well. This interval's width depended on the size of the transaction costs. Increasing the size of transaction costs would result in a lager no-transaction region. As the size of transaction costs converged to zero, the no-transaction region would converge to the optimal risky asset share as in Merton's (1969) model.

Dumas and Luciano (1991) found similar results. They set up a two-asset portfolio model with transaction costs and assumed the individual maximizes terminal wealth and consume all that wealth at the terminal time. The terminal time was postponed to the future so that "a stationary portfolio rule" could be found (Dumas and Luciano, 1991, p578). The exact solution they derived also suggested that there was a (S,s) type rule in the risky asset allocation problem.

Since the models in Constantinides (1986), Davis and Norman (1990), Dumas and Luciano (1991) are all set up in an infinite horizon framework, the optimal asset allocation rule were all found to be time independent (Liu and Loewenstein, 2002, p807). In contrast, Liu and Loewenstein (2002) set up a two-asset portfolio model with transaction costs in a finite horizon framework. In order to highlight the impact of time horizon on portfolio choice, the utility of maximizing terminal wealth was assumed and no consumption was taking place during the lifetime. They found that "investor may optimally never buy the risky asset subject to transaction costs if the expected horizon is short" (Liu and Loewenstein, 2002, p807).

To sum up, in the above papers, such as Constantinides (1986), Davis and Norman (1990), Dumas and Luciano (1991), and Liu and Loewenstein (2002), labour income were all not assumed in the models, so the investor only needed to rebalance his/her portfolio allocations between the risk-free asset and risky assets in order to maximize his/her utility. In all of these papers, a (S, s) type rule was found for the optimal portfolio allocation problem, this implied, in a friction environment, that there should be slower portfolio adjustment or lower frequency in asset trading and more fluctuations in portfolio shares than in a frictionless environment. For example, the model in Liu and Loewenstein' (2002, p829) paper predicted that with reasonably calibrated parameters, for a 1 percent transaction cost, it took about five years for an investor with expected 25 years ahead to sell his/her risky asset after a purchase, whereas in a frictionless environment, an investor needed to trade continuously.

2.7.2.3 Explaining low participation rate

Since empirically a high rate of non-participation in the stock market has been commonly observed, short-sale constraints, transaction costs, together with lifecycle considerations, such as background risk, are introduced to explain this phenomenon (Curcuru, 2004). However, background risk alone cannot explain the large number of non-participation in the stock market, because it can only change the optimal risky asset share. Even if the returns of risky assets are assumed to be highly correlated with large background risks, the investors may possibly not buy the risky assets or even short sell risky assets but their demand for risky assets is "exactly zero is negligible" (Curcuru, 2004, p17). Therefore, typically when a portfolio model is set up, short sales constraints would be imposed. By imposing this constraint, the demand for a risky asset would be left censored at zero which is consistent with the empirical observation that a large number of individuals do not invest in risky assets. Transaction costs, however, which are only be found in research to explain a slow adjustment speed in the portfolio rebalancing process, also, together be found that together with life-cycle considerations transaction costs, "appear necessary to explain the lack of stock market participation by young and less affluent households" (Curcuru, *et al.*,2004, p1).

Gomes and Michaelides (2005) incorporated uninsurable labour income, transaction costs and Epstein–Zin preferences into the consumption/portfolio choice model. Different from previous models which did not consider labour income risk and the primary reason to do the transaction was portfolio rebalancing, the model introduced by Gomes and Michaelides (2005) was to maximise consumption overtime. Gomes and Michaelides (2005) found that in a life-cycle model where young households anticipated a high growth rate in their future labour income and they were liquidity constrained in terms of borrowing constraints and short-sale constraints, they prefer to consume rather than invest. If they invested, the potential investment income from their limited savings would not be able to offset the fixed participation cost and/or proportional transaction cost (Curcuru, 2004, p26). Hence, it would be better for the young households to accumulate enough wealth before they participated in the stock market (Gomes and Michaelides, 2005, p884). Analogically, the transaction cost can explain the low participation rate in the stock market by less affluent households (Curcuru, 2004, p1). In addition, Heaton and Lucas (1997) found that transaction costs could affect households' portfolio choice by inducing a tilt in the portfolio toward assets which had lower transaction costs (Curcuru, *et al*., 2004, p14).

Among recent studies, we also find that many researchers suggested that even a small participation cost could explain the low participation rate in the stock markets which were empirically observed. For example, Vissing-Jorgensen (2002, p33) set up a dynamic sample selection model and showed that just $ 50 per period transaction cost could be sufficient to explain half of the non-participants. Similarly, by using the US Consumer Expenditure Survey, Paiella (2001, p1) found that after controlling for the wealth effect and demographic effect, an annual transaction cost of at least $70 could induce a rational representative agent with log utility not to participate in the stock market. More recently Polkovnichenko (2007) suggested that the fixed transaction cost that was needed to prevent households from participating in the stock market was not very high if "heterogeneous risk aversion and heterogeneous idiosyncratic income risk" were introduced into the model (Curcuru, *et al*., 2004, p29).

Some researchers, for example Jang *et al.* (2007) and Leirvik and Trojani (2010), looked at the issue of liquidity premium[13] and transaction costs by setting up a consumption/portfolio model in a regime-switching framework with a time-varying investment opportunity set. Leirvik and Trojani (2010, p5,-p6) found that for a proportion transaction cost of one percent, the liquidity premium was large[14] enough to conclude that "together with an incomplete market, transaction costs might be a possible solution of the equity premium puzzle". This could partially explain the low participation rate in the stock market because with transaction cost the gains from investing in risky assets were much lower than the gains with zero transaction cost. Hence, transaction costs discouraged participation in the stock market.

2.7.3 The effect of taxation

Like labour income risk, housing, and transaction cost, taxation is also an important factor that can influence households' portfolio allocations. Here we follow King and Leape' (1998) idea and summarise that there are two approaches via which taxation can have an impact on portfolio choices. The first approach is that among different asset classes with different tax preference, individuals who have different effective tax rates can choose to invest on those assets which can maximise their post-tax income. For example, empirical studies carried out by King and Leape (1998, p176) suggest that individuals who have to pay a high marginal tax rate tend to hold tax-exempt assets and/or tax preferred assets, such as municipal bonds and corporate equity, whereas the holders of taxed assets, for example, the holders of "liquid and less

[13] Liquidity premium refers to the maximum expected return which a household is willing to give up for zero transaction costs (Constantinides, 1986).

[14] For a proportion transaction cost of one percent, the lower bound and the upper bound of liquidity premium is 3.5 percent and 3.6 percent respectively (Leirvik and Trojani, 2010, p5).

liquid savings" are found to be the individuals who face low marginal tax rates. Some scholars, such as Shoven and Sialm (2003) and Dammon *et al.* (2004), set up theoretical models to investigate this issue and generally concluded that "placing relatively highly taxed investments in tax protected accounts is optimal" (Curcuru, *et al.*, 2004, p15). Shoven and Sialm (2003, p23) suggested that for a risk averse individual who was in the high tax brackets, should put taxable bonds and stocks in tax-deferred accounts and put tax-exempt municipal bonds in taxable accounts. The numerical analysis in Dammon *et al.*(2004) also showed that due to the higher tax rate imposed on taxable bonds relative to stocks, individuals were more willing to allocate taxable bonds in tax-deferred accounts and allocate stocks in taxable accounts.

The second approach via which taxation can have an impact on portfolio choices is that the taxation could have an impact on the demand for risky assets, but this impact is theoretically ambiguous (King and Leape, 1998, p177). Tobin (1958, p81) explained that if an risk averse individual could only invest in two assets, a risk-free asset with no yield and a risky asset whose return is normally distributed, then introducing a tax on "interest income and capital gains alike, with complete loss offset provisions" would cause the individual to invest a higher proportion of wealth in a risky asset. Later, Mossin (1968) found that as long as the individual had a concave utility function and the risk-free asset had no yield, the impact of tax on risky asset allocations would be positive, no matter if the risky asset's return follows a normal distribution or not. However, the impact of the proportional taxation on risky asset allocation would be ambiguous if the assumption that risk-free asset had no yield does not hold (Feldstein, 1976, p633). Therefore, if we want to examine the impact of taxation on portfolio allocations between risky assets and risk-free assets with a yield, we can follow the two-effect approach which was introduced by Tobin (1958). In section 4 of Chapter 5, we present a theoretical framework in detail and show how the substitution effect and the wealth effect could work together to determine the overall impact of taxation on an individual's portfolio allocation. We also carry out an empirical study using the BHPS data and a positive impact of marginal tax rates on individual's risky asset shares is found. Our findings are consistent with many other empirical work, which have been listed and summarised in the following Table 2.3 and Table 2.4.

Table2. 3: Some US studies on the effect of taxation

Authors	Data	Methodology	Findings	MTR
Hubbard (1985)	Uniquely collected by the US President's Commission on Pension Policy in 1979 and 1980	Probit Asset demand equations	His work suggests that after controlling for income and wealth, the differences in households' marginal tax rates could explain the cross sectional variation in households' portfolio allocation.	Estimate individual MTR using the NBER TAXSIM program
Scholz (1994)	Surveys of Consumer Finances conducted in 1983 and 1989	Intertemproal analysis	It seems that the Tax Reform Act of 1986 did not significantly affect household portfolio decisions even though the marginal tax rates facing many households were affected.	Author's calculations
King and Leape (1998)	A special high-net-wealth survey conducted in 1978 by the Stanford Research Institute (SRI)	Probit Asset demand equations	Taxation has significant impact on the ownership for different categories of assets. Conditional on the ownership, it has limited impact on the proportion of investment in different classes of assets.	Using detailed survey data to calculate precisely the marginal tax rate facing each household.

Poterba and Samwick (2003)	Surveys of Consumer Finances over 1983, 1989, 1992, 1995 and 1998	Probit and Tobit models	Effect on ownership is substantial eg: the probability that a household owns tax-advantaged assets is positively related to its tax rate on ordinary income. They find the portfolio share invested in corporate stock is increasing in the tax rate.	Develop a new algorithm for imputing federal MTR to households.

Table2. 4: Some Non-US studies on the effect of taxation

Authors	Data	Methodology	Findings	MTR
Agell and Edin (1990)	Annual Swedish Income Distribution Survey	Probit Asset demand equations	They find significant impact of taxation on portfolio decisions: an increase of one-percentage-point in the MRT could boost the proportion of net wealth invested in common stocks by two percent (from 20 percent to 20.4 percent).	Author's calculations
Hochguertel *et al.* (1997)	The Dutch Collective Bank Study in 1988	Tobit	Results show that the level of financial wealth and the marginal tax rate are major determinants of the allocation between risk-free assets and risky assets.	The measure for the marginal tax rate has been constructed from this variable and the parameters of the Dutch tax system in 1988.
Stephens and Ward-Batts (2004)	UK Family Expenditure Survey (FES) data	DD estimation	Households responded to this policy change by reallocating asset ownership.	Author's calculations
Alan *et al*. (2010)	Canadian Survey of Consumer Finances (SCF) from 1986 to 1991	DD estimation	Canadian couples reallocate asset ownership to minimize tax liabilities.	Author's calculations

3. Household-Specific Factors and Risky Asset Choice

3.1 Introduction

Theory suggests that the proportion of wealth invested in risky assets should be constant regardless of the investors' ages or wealth if we assume investment opportunities are constant and investors' utility has constant relative risk aversion (Merton 1969, 1971). Empirical studies reveal that the age has positive or has an inverse-U shape effect on individual's risky asset allocation in the US (Ameriks and Zeldes, 2004), in the European countries such as UK, Netherlands, Germany, Italy (Guiso *et al.,* 2002) and in Japan (Iwaisako, 2009). Furthermore, investment advisors typically would suggest younger investors hold a portfolio with relatively high risk. As they age, the investment time horizon shrinks and a reduction in risk is appropriate so that, not surprisingly, older investors would be advised to invest most of their wealth in risk-free assets (Bali *et al.,* 2009). Malkiel concluded that the investors' risky portfolio share should equal "100 minus the investor's age" (Malkiel, 1999, p418).

Furthermore, theory predicts wealth has no impact on the optimal risky portfolio share under classical assumptions, including individual preference with CRRA, constant investment opportunities or the individual with log utility function, and no labour income is generated. However, empirical studies generally reveal a positive correlation between the proportion of wealth invested in risky assets and households' wealth after controlling for the level of education and other demographic variables (Wachter and Yogo, 2010). Furthermore, theory predicts a much higher stock market participation rate and higher proportion of investment in stocks than is observed (Guiso *et al*., 2002; McCarthy, 2004; Iwaisako, 2009).

Incorporating factors, such as transactions costs and borrowing constraints (Constantinides, 1986; Davis and Norman, 1990; Heaton and Lucas, 1997), life-cycle considerations (Gomes and Michaelides, 2003; Polkovnichenko, 2007; Cocco *et al.,* 2005), and the variation in background risk exposure from sources, such as labour and entrepreneurial income or real estate holdings (Cocco *et al.,* 2005; Viciera, 2001), can explain the cross-sectional variation in portfolio allocation.

In this chapter we consider how such factors influence portfolio variation from a household perspective. We use data from the UK Panel Household Survey (BHPS) which provides evidence on a sample of around 3000 household, of choice of risky asset portfolio. We identify a set of household specific factors which are observed to influence risky asset choice. From a theoretical perspective we identify both the risk aversion parameter and habit formation as mechanisms by which the household specific variables influence choice. We do not believe systematic variation in household beliefs can explain choice and hence ignore this as a possibility. We use a Tobit model and censored quantile regression (CQR) model for UK based data from the BHPS so as to identify factors that influence household asset allocation decisions and then interpret the cross-sectional variation in asset allocation in the context of observed risk aversion of households.

The remaining part of this chapter is organized as follows. Section 3.2 briefly outlines the theoretical considerations and then identifies how it can explain household variation in risky asset selection. Section 3.3 discusses our data set, empirical methodology and reports our results. Section 3.4 interprets these results and provides some concluding comments.

3.2 Theoretical foundations

Early work on portfolio theory is set in a static one-period setting (Markowitz, 1952, Tobin, 1958) and involves maximising a utility function of wealth. The principles established in that work are incorporated into dynamic specifications (Samuelson (1969) and Merton (1969, 1971)). However, such models are found to contain propositions that are not empirically justified, predicting too high a proportion of risky assets in portfolios and failing to explain the age profile of the risky asset holding. Merton (1969) suggested that, under restrictive assumptions including constant relative risk aversion and constant investment opportunities, the risky asset allocation decision is independent of the investment time horizon and the investor's wealth. However, if investment opportunities vary over time, multi-period investors will be also concerned about hedging consumption against shocks due to time-varying expected returns and/or covariances. As a consequence portfolio models, where consumption is the key driver of utility, are developed to handle the possibility of inter-temporal hedging which arise naturally from time-varying returns (Campbell *et al.,* 2003; Chacko and Viceira, 2005). Such models are observed to describe what is called ‘‘strategic asset allocation’’ (Brennan *et al.*, 1997, p1377).

Empirical analysis has also demonstrated the failing of the basic Merton model. An inverse-U shape of age effect on individual’s risky asset allocation has been found in a wide range of empirical studies (Ameriks and Zeldes (2004), Italy (Guiso *et al.,* 2002) and in Japan (Iwaisako, 2009). There appears to be a positive correlation between the proportion of wealth invested in risky assets and household wealth (Wachter and Yogo, 2010). Guiso *et al.* (2002, Table I.7) documented this fact for five countries, namely the US, the UK, Netherland, Germany and Italy, based on various household surveys. Similar correlation has also been found in early household surveys, for example, for the US, the 1962 and 1963 Federal Reserve Board Surveys of the Financial Characteristics of Consumers and Changes in Family Finances (Blume and Friend, 1975; Friend and Blume, 1975; cited in Wachter and Yogo, 2010, p3). Wealth does not only have an impact on stock market participation but also has an impact on the risky portfolio share. The probability of low wealth individuals investing in risky assets is much smaller than the probability for the rich and, even conditional upon participation, the poor tend to invest less in risky assets. As also has been suggested in many empirical studies, after controlling for the level of education and other demographic variables, wealth is still found to have positive effect on risky portfolio share (Wachter and Yogo, 2010).

A number of factors, which are likely to influence portfolio selection, have been analysed theoretically. Among then we note transactions costs and borrowing constraints (Constantinides, 1986; Davis and Norman, 1990; Heaton and Lucas, 1997), restricted pension investments (Curcuru *et al.,* 2006), life-cycle considerations (Gomes and Michaelides, 2003; Polkovnichenko, 2007; Cocco *et al.,* 2005), and the variation in background risk exposure from sources such as labour and entrepreneurial income or real estate holdings (Cocco *et al.,*2005; Viciera, 2001). As a consequence cross-sectional variation in asset allocation has been more fully explained, although differences between the theory and empirical observation still remain (Cauley *et al.,* 2007). Cocco (2005) found that housing can dramatically improve the predictability of the standard optimising model. By adding housing into the model, the predicted age profile of risky asset selection moves to greater consistency with empirical studies (McCarthy, 2004, p25). Flavin and Yamashita (2002), Campbell and Cocco (2003), Marshall and Parekh (1999), and Hu (2005), also studied the impact of housing on asset allocation and, generally, observed that housing "crowds out risky asset holdings" (McCarthy, 2004, p28; Cauley *et al.*, 2007). Households in the UK appear to hold more risky portfolios than those in the US and housing ownership is used to explain this (Banks *et al.*, 2002a).

The introduction of habit into the utility function has helped to bring theoretical predictions of asset pricing closer to empirical observation (explaining the equity premium). Less work has been done on introducing habit into the portfolio choice decision. However, recent papers suggest that such a modification can help to explain age profile, income and wealth effects and potentially the impact of housing wealth (eg: Polkovnichenko, 2007; Gupta, 2009). The key thing to note is that habit allows risk aversion to vary significantly, particularly for consumption levels close to the habit level, and hence participation rates and levels of risky assets below expectation can be understood with such an innovation.

3.3 Data, empirical model and methodology

3.3.1 Data

We use data from the British Household Panel Survey (BHPS), which is a general household panel survey and has been seldom used to study household portfolio allocation and saving behaviour (although see Guariglia, (2001); Guariglia and Rossi (2002); Banks *et al.* (2002b)). The BHPS is a UK annual survey, started from 1991 with an initial sample size of 5,500 households and 10,000 people are roughly involved. The sample is "a stratified clustered design drawn from the Postcode Address File and all residents present at those addresses at the first wave of the survey were designated as panel members" (BHPS, 2010). Whenever new families are formed or separated from their parent's household, the new family members and the old both get re-interviewed every year, with the exception of children under 16. In total, the survey has conducted eighteen waves from 1991 to 2008. The data for the first seventeen waves are available to scholars, while Wave 18 data is in process and will be published in 2010. Detailed questionnaire content and other information related to the survey are provided by the University of Essex (BHPS, 2010).

BHPS is a panel survey and it has been reported that there is a high proportion of respondents who were interviewed in 1991 till present in the subsequent surveys. The proportion is around 62% for the 2000 BHPS. Furthermore, data information on household composition, housing conditions, residential mobility, education and training, basic consumption, labour market behaviour, income from employment, benefits and pensions are available for each wave survey and can be accessed via the UK data archive. In contrast, detailed data on financial wealth are only collected every five years starting from 1995. In 1995, 2000, 2005, 2010 BHPS, respondents were required to report information on savings, investments and debts separately. They were asked what kind of savings and investments they hold, how much of the total amount they saved, how much of the total amount they invested and how much of the total amount they owed.

3.3.2 Definition of variables

In this thesis we employ a standard measure of "liquid wealth" which is defined to include both risky assets (investments) and risk-free assets (savings). Our dependent variable, *proportion of liquid wealth invested in risky assets in 2000 (*α_{2000}*)*, is defined as is the amount of valid investment in risky assets divided by total valid investment in both risky and risk- free assets at the time when the survey was carried out in 2000.

According to classification in BHPS, savings include saving or deposit account (with a bank, post office or building society), National Savings Bank (Post Office), TESSA or ISA. Investments consist of National Savings Certificates, Premium Bonds, Unit Trusts/Investment Trusts, Personal Equity Plan, Shares (UK or foreign), National Savings bonds (Capital, Income or Deposit), and other investments (government or company securities). Housing and pensions are not classified as investment products.

From our review of theory and previous empirical studies we have identified a series of variables that we think will be important in explaining the risky asset selection of individual household. Using the data collected from the BHPS survey in 2000 and 1995, we construct the following variables, some of which have been used in previous studies of asset allocation:

The *proportion of liquid wealth invested in risky assets in 1995 (α_{1995})* is the amount of valid investment in risky assets divided by total valid investment in both risky and risk-free assets at the time when the survey was carried out in 1995 (we have a similar definition for 2000).

Net liquid wealth (NETLIQUIDWEALTH) is the sum of total savings and investments in 2000, minus personal debt in 2000; *NETLIQUIDWEALHTSQUARED* is the square value of *NETLIQUIDWEALTH*.

Personal debt (PERSONALDEBT) is the respondents' personal debt in 2000 including "hire purchase agreements, personal loans (from bank, building society or other financial institution), unpaid credit cards (including store cards), catalogue or mail order purchase agreements, DSS social fund loan, overdrafts, any other loans from a private individual, overdrafts, student loan and other debts[15].

Gross house value (HOUSING) is the expected house value perceived by the households in 2000; *HOUSINGQUARED* is the square value of *HOUSING*.

Net house value (NETHOUSING) is equal to gross house value in 2000 minus any outstanding mortgage loans. *NETHOUSINGSQUARED* is the square value of *NETHOUSING*.

OUTSTANDINGMORTGAGE equals total amount of outstanding mortgage loans on the properties that are owned by the respondent or his/her family members in 2000.

Labour income *(LABOURINCOME)* is the respondent's annual labour income before tax in 2000.

[15] "For a full list of which products are included as savings, investments and debt, see Annex B." (Bank *et al,* 2002b).

Income to net liquid wealth ratio (INCOMENLW) is the respondent's annual income before tax in 2000 divided by his/her net liquid wealth.

Age (AGE) is the respondent's age in 2000. *AGESQUARED* is the square value of *AGE.*

Education dummy variables include *OLEVELORUNDERDUM, ALEVELDUM* and *DEGREEDUM*. *OLEVELORUNDERDUM* equals one if the respondent's highest education level is O level or under[16], and it equals zero otherwise. *ALEVELDUM* equals one if the respondent's highest education level is an A-level or equivalent[17], and it equals zero otherwise. *DEGREEDUM* equals one if the respondent's highest education level is first degree or higher[18], and the dummy variable equals zero otherwise. The respondent whose highest education is an O-level or under is set to be the base category and the dummy variable for this education level is not included in the regression. All these education dummy variables are set up based on the information given in the 2000 BHPS survey.

Pension dummy (PENSIONDUM) equals one if the respondent reported that he/she belongs to his/her employer's pension scheme and/or private personal pensions in 2000, and the dummy variable equals zero otherwise.

Dummy variables for *employment status* have also been generated, including *EMPLOYEEDUM, SELFEMPLOYEDDUM, RETIREDDUM and UNEMPLOYEDDUM. EMPLOYEEDUM* equals one if the respondents is in paid employment, and it equals zero otherwise. *SELFEMPLOYEDDUM* equals one if the respondent is self employed and it equals zero otherwise. *RETIREDDUM* equals one if the respondent reported

[16] O level or CSE, GCSE.

[17] A level or HNC (Higher National Certificate) or HND (Higher National Diploma), Teaching qualifications, Nursing qualifications

[18] first degree or higher degree

himself/herself as being retired and it equals zero otherwise. *UNEMPLOYEDDUM* equals one if the respondent is out of labour force and it equals zero otherwise. The group of respondents who are retired is set to be the base category for the employment status. All these employment status dummy variables are set up based on the information given in 2000 BHPS survey.

Sex dummy (SEXDUM) equals one if the respondent is male in 2000, and it equals zero otherwise.

Marital status dummy (MARITALDUM) equals one if the respondent is legally married in 2000, and it equals zero if he/she is either separated, divorced, widowed or just single.

Children dummy (CHILDDUM) equals one if the respondent is living in a family that has one or more than one child aged 12 or under in 2000, and it equals zero otherwise.

Finally,

Region London dummy (LONDONDUM) is defined that it equals one if the respondent lives in the greater London in 2000, and it equals zero otherwise.

3.3.3 Data descriptions

We select the group of individuals who attended both the 1995 BHPS and 2000 BHPS interviews. The number of individuals in this group is 2484. Table 3.1 presents the distribution of savings, investments, personal debts, total liquid wealth and total net liquid wealth for our sample of 2484 observations from the 2000 BHPS. Table 3.2 shows the breakdown of total net liquid wealth for the same sample. As we can see from the Table 3.1 and Table 3.2, the average savings of these 2484 respondents is £7,281 whereas the median amount of savings is just £2,000; the average investments in risky assets is £7,067, whereas the median amount of investments in risky assets is £15. Similarly, the average values of personal debts, total liquid wealth and total net liquid wealth are all much higher than the corresponding median values. These large differences between the average values and median values suggest that in terms of each asset classes, there is a small proportion of individuals who hold a large amount of it. If we consider the wealth distribution by percentiles, as detailed in Table 3.1, we get further insights. We observe that from 2484 individuals, the lower 50% have £2,000 or less of savings whereas the top 10 percent have at least £17,000 of savings. Compared with the distribution of savings, the distribution of investments in risky assets is much more heavily skewed. The bottom 50 percent of the distribution invest £15 or less in risky assets, and the top 10 percent invest at least £15,875 in risky assets. Individuals in our sample size have a low participation rate in risky investments. Upon participation, the median as well as 75 percentile and 90 percentile values of the risky investments are still much less than those values of savings. Table 3.1 also reveals there is a large inequality in terms of net liquid wealth in our sample. The group of individuals who are in the bottom 25 percent have only £150 of net liquid wealth whereas the group of individuals who are at the top 25 percent have roughly 75 times that at £11,300. In sum, Table 3.1 suggests that there are large variations across households' asset allocations and their wealth and that there is a significant skewness towards the upper end of the distribution.

Table 3. 1The Distribution of Liquid Wealth in 2000

ASSET CLASS	Obs	10 Percentile	25 Percentile	Median	75 Percentile	90 Percentile
Savings (investment in risk free asset)	2484	5	350	2000	7000	17000
Investments in risky assets	2484	0	0	15	3000	15875
TOTOAL LIQUID WEALTH	2484	100	800	3800	12000	36125
Personal debt	2484	0	0	0	1000	5000
TOTAL NET LIQUID WEALTH	2484	-2492	150	3000	11300	35110

Table 3.2 shows the breakdown of total net liquid wealth for our 2484 sample. On average, the net liquid wealth consists of 56.85% in savings, 55.18% in investment in risky assets, and -12.02% in personal debt.

Table 3. 2The Composition of Liquid Wealth

ASSET CLASS	Obs	MEAN	Std.Dev.	PERCENTAGE
Savings (investment in risk-free asset)	2484	7281	17439	56.85%
Investments in risky assets	2484	7067	25062	55.18%
TOTAL LIQUID WEALTH	2484	14348	33999	112.02%
Personal debt	2484	-1540	4352	-12.02%
TOTAL NET LIQUID WEALTH	2484	12808	107504	100.00%

Despite the high average holdings of risky asset, it is heavily skewed. Figure 3.1 and 3.2 suggests that 45 percent of these 2484 respondents have no risky investments at all in 1995. Beyond that 8% report only risky asset holding while the remainder are distributed across the range. Table 3.3 below confirms these results.

Figure 3. 1:Spike plot of risky asset shares in 1995 (α1995)

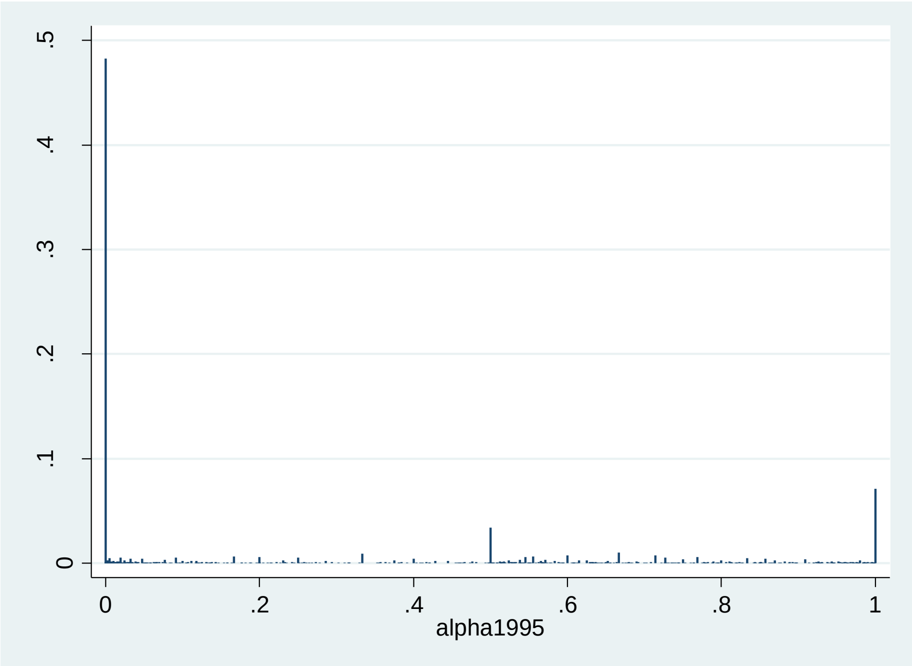


Figure 3. 2:Spike plot of risky asset shares in 2000 (α2000)

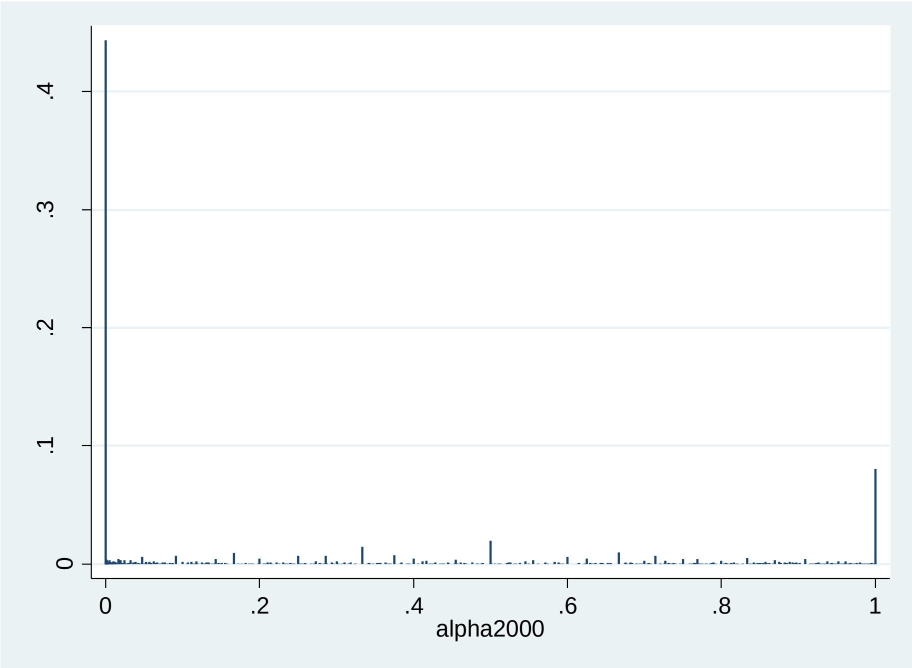


Table 3.3 reports descriptive statistics for our explanatory variables. We may note that wealth and income is unequally distributed and this provides insight into the pattern of risky asset selection which is discussed in our empirical specification. Notice also that we have missing observations for some of our key explanatory variables. Since we don't think that the reporting of data is determined by factors that affect risky asset holding this is not likely to represent an econometric problem. The overall message of our descriptive statistics indicates that we have a representative sample of UK households that will allow us to provide useful insights into factors that influence their risky asset choice.

Table 3. 3: Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	10 Percentile	25 Percentile	Median	75 Percentile	90 Percentile
α2000	2484	0.28	0.37	0	0	0.01	0.56	0.96
α*1995*	2484	0.27	0.36	0	0	0	0.55	0.94
NETLIQUIDWEALTH	2484	12808	34488	-2492	150	3000	11300	35110
PERSONALDEBT	2484	1540	4352	0	0	0	1000	5000
HOUSING	2484	101229	93929	0[19]	45000	80000	140000	210000
NETHOUSING	2408	74416	86509	0	16000	53000	100000	182300
OUTSTANDINGMORTGAGE	2408	25523	44148	0	0	3000[20]	40000	70000
LABOURINCOME	2484	10592	288	0	0	4438	17160	29173
INCOMENLW	2470	26	8	-3.19	0	0	2.34	12
AGE	2484	49	18	27	35	47	62	75
OLEVELORUNDERDUM	2473	0.58	0.50	0	0	1	1	1
ALEVELDUM	2473	0.27	0.45	0	0	0	1	1
DEGREEDUM	2473	0.15	0.36	0	0	0	0	1
PENSIONDUM	2484	0.45	0.50	0	0	0	1	1
EMPLOYEEDUM	2294	0.62	0.49	0	0	1	1	1
SELFEMPLOYEDDUM	2294	0.07	0.26	0	0	0	0	0
RETIREDDUM	2294	0.26	0.44	0	0	0	1	1
UNEMPLOYEDDUM	2294	0.05	0.21	0	0	0	0	0
SEXDUM	2484	0.47	0.50	0	0	0	1	1
MARITALDUM	2484	0.62	0.49	0	0	1	1	1

[19] Although the 10 percentile of gross housing value distribution is zero, there are actually 17 percent of respondents (i.e.: 420 out of 2484) who doesn't own his/her accommodation.

[20] Although the median is £3000, there are 49 percent of respondents(i.e.: 1173out of 2408) who has zero outstanding mortgage loans.

CHILDDUM	2484	0.22	0.42	0	0	0	0	1
LONDONDUM	2484	0.10	0.29	0	0	0	0	0

The Table 3.4 presents how the risky asset shares in 2000 vary by net liquid wealth, personal debt, gross housing value, net housing value, outstanding mortgage loan, annual labour income, ratio of labour income to net liquid wealth.

Table 3. 4: The distribution of risky asset shares in 2000 (α2000)

	Risky asset shares (α2000) at percentiles and mean				
	Obs	**25th**	**Median**	**75th**	**Mean**
Net liquid wealth quintile					
Lowest	497	0	0	0.40	0.23
2nd	497	0	0	0.17	0.19
3rd	497	0	0	0.29	0.19
4th	497	0	0.11	0.55	0.30
Highest	496	0.11	0.50	0.81	0.48
Personal debt quintile					
Lowest	497	0	0	0	0
2nd	497	0	0.02	0.12	0.07
3rd	497	0.51	0.74	0.94	0.72
4th	497	0	0	0.60	0.27
Highest	496	0	0.04	0.68	0.32
Gross housing value quintile					
Lowest	497	0	0	0.12	0.17
2nd	497	0	0	0.33	0.21
3rd	497	0	0.05	0.59	0.29
4th	497	0	0.11	0.67	0.32
Highest	496	0	0.29	0.77	0.39
Net housing value quintile					
Lowest	482	0	0	0.13	0.18
2nd	482	0	0	0.5	0.25
3rd	482	0	0.01	0.51	0.27
4th	481	0	0.06	0.62	0.31
Highest	481	0	0.32	0.75	0.39

Outstanding mortgage quintile					
Lowest	497	0	0	0	0
2nd	497	0.02	0.19	0.50	0.28
3rd	497	0	0.54	0.99	0.49
4th	497	0	0	0.50	0.27
Highest	496	0	0.17	0.74	0.35
Annual labour income quintile					
Lowest	497	0	0	0	0
2nd	497	0.06	0.33	0.63	0.37
3rd	497	0	0.17	1	0.43
4th	497	0	0	0.50	0.25
Highest	496	0	0.17	0.70	0.34
(labour income/nlw) quintile					
Lowest	497	0	0	0	0.15
2nd	497	0	0	0	0
3rd	497	0.38	0.67	0.96	0.64
4th	497	0	0.25	0.71	0.36
Highest	496	0	0	0.38	0.23

The main message of Table 3.4 is that at the lowest percentiles we have a preponderance of households which hold zero risky assets and these households also have low income, low wealth and don't own real estate. At higher quantiles we observe relationships which would be expected, namely that increases in income, wealth and housing wealth increase the share of risky assets in the portfolio.

The following Table 3.5 presents how the risky asset shares in 2000 varies by age, education level, pension status, employment status, gender, marital status, number of children and living area. We observe that age has an inverse-U shape relationship with the risky asset shares. Risky asset shares increase in education level. Similarly, having an occupational pension plan and/or private pension plan is associated with an increasing risky asset share. In terms of employment status, Table 3.5 suggests that unemployed respondents hold the lowest risky asset shares among all the respondents. In addition, male respondents are found to allocate a higher proportion of wealth in risky assets. Marriage and having at least one child with age less than 12 is also linked positively to risky asset share. The impact of region is limited.

Table 3. 5: The distribution of risky asset shares in 2000 (α2000)

	Risky asset shares (α2000) at percentiles and mean				
	Obs	**25th**	**Median**	**75th**	**Mean**
Age band					
<25	160	0	0	0	0.11
25-29	183	0	0	0.14	0.16
30-34	244	0	0	0.55	0.27
35-39	288	0	0.01	0.49	0.27
40-44	252	0	0.25	0.80	0.38
45-49	221	0	0.05	0.67	0.31
50-54	248	0	0.06	0.56	0.28
55-59	187	0	0.15	0.67	0.34
60-64	154	0	0.27	0.68	0.37
65-69	138	0	0.03	0.82	0.33
70-74	147	0	0.12	0.68	0.34
75+	262	0	0	0.24	0.20
Education level					
O-Level or under	1413	0	0	0.50	0.25
A-Level or equivalent	679	0	0.02	0.60	0.29
Degree or above	381	0	0.18	0.71	0.35
Pension status					
No pension	1366	0	0	0.50	0.26
Occ. Pension	843	0	0.05	0.63	0.30
Pers. Pension	401	0	0.17	0.69	0.33
both	126	0	0.18	0.68	0.35
Employment status					

Employee	1416	0	0	0.56	0.28
Self employed	172	0	0.20	0.58	0.31
Retired	602	0	0.03	0.65	0.30
Unemployed	104	0	0	0.28	0.18
Gender					
Male	1167	0	0.07	0.67	0.31
Female	1317	0	0	0.50	0.25
Marital status					
Married	1544	0	0.05	0.64	0.30
Others	940	0	0	0.43	0.23
No. of children(age<12)					
1+	555	0	0.05	0.68	0.32
0	1929	0	0	0.52	0.27
Living area					
Greater London	238	0	0.03	0.58	0.28
Others	2246	0	0	0.55	0.27

From Figure 3.1, Figure 3.2 and Table 3.3, we may note that the distribution for the share of risky assets of an individual in 2000 is similar to that in 1995. However, we find there are changes in the risky asset share for our sample between 1995 and 2000, reported in Table 3.6. As we can see from Table 3.6, in 1995, 1199 out of 2484 respondents do not have any risky investments. Among these 1199 respondents, there are 812 individuals still do not invest in risky assets in 2000. Of the remaining 387 individuals, 202 invest less than half of their total liquid wealth in risky assets, 16 individuals invest exactly half, 108 individuals invest more than half, and 61 individuals invest all of their total liquid wealth in risky assets. Based on Table 3.6, we calculate that 52 percent of respondents in our sample (i.e.1299 out of 2484 individuals) do not move out their risky asset share bracket. This comprises 234 individuals who keep their risky asset shares in the range between zero and 0.5, 205 individuals whose share stay in the 0.5-1 bracket, and 860[21] respondents who invest either zero, 50 percent or 100 percent of their total liquid wealth in 1995 and remained their risky asset share exactly the same in 2000. As can be seem from Table 3.6, 812 out of 1199 individuals (i.e. 68 percent) who hold no risky assets in 1995 still do not invest in them in 2000. More than a quarter of respondents (i.e. 46 out of 177 individuals) who invest all their liquid wealth in risky asset in 1995 are found to stay in the same position in 2000. In addition, 2 individuals invest exactly half of their total liquid wealth in risky assets in both years. Thus, to sum up, at least 35 percent of total respondents (i.e. 860 out of 2484 respondents) do not change their risky asset share at all in 2000 and 52 percent of total respondents in our sample (i.e.1299 out of 2484 individuals) do not move out their risky asset share bracket. These imply that more than half of our 2484 respondents changed their risky asset share in year. One purpose of our analysis is to identify factors that can explain these changes in risky asset share.

Table 3. 6: Changes in individual's Risky Asset Share from 1995 to 2000

	Risky Asset Share in 2000 (*α2000*)					
Risky Asset Share in 1995 (*α1995*)	**0**	**(0,0.5)**	**0.5**	**(0.5,1)**	**1**	**Total**
0	812	202	16	108	61	1199
(0,0.5)	118	234	13	92	42	499
0.5	26	40	2	13	3	84
(0.5,1)	89	169	14	205	48	525
1	56	35	4	36	46	177
Total	1101	680	49	454	200	2484

[21] The number of 860 is the sum of 812, 46 and 2.

3.3.4 Empirical model and methodology

The main equation in the model that we are going to estimate is as follows:

$$\alpha^*_{2000i} = (1-\beta_0)\alpha_{1995i} + \beta_1\, netliquidwealth_i + \beta_2 netliquidwealthsquared_i +$$

$$\beta_3 personaldebt_i + \beta_4 housing_i + \beta_5 housingsquared_i + \beta_6 outstandingmortgage_i +$$

$$\beta_7 incomenlw_i + \beta_8 age_i + \beta_9 agesquared_i + \beta_{10} aleveldum_i + \beta_{11} degreedum_i +$$

$$\beta_{12} pensiondum_i + \beta_{13} employeedum_i + \beta_{14} selfemployeddum_i + \beta_{15} unemployeddum_i +$$

$$\beta_{16} sexdum_i + \beta_{17} maritalstatus_i + \beta_{18} childdum_i + \beta_{19} londondum_i + \varepsilon_i\,,\ \ \varepsilon_i \sim N(0,\sigma^2)\,,$$

which is derived from the following equation:

$$\alpha_{2000} = \alpha_{1995} + \beta(\alpha^*_{2000} - \alpha_{1995}) = (1-\beta)\alpha_{1995} + \beta\alpha^*_{2000} = (1-\beta)\alpha_{1995} + \beta * f\ (\gamma, r\,,\ \mu_t\,, \sigma, \sigma_X\ ,\ \lambda_X\,).$$

where α *2000* and α *1995* are the proportion of liquid wealth invested in risky assets in 2000 and 1995 respectively, derived by using BHPS data; α^*_{2000} is the optimal risky asset allocation rule. The basis for this specification is a partial adjustment equation due to transaction costs. This therefore incorporates a particular feature of assets markets which have been identified as important in explaining asset choice, namely transactions costs. The question arises which variables should appear in influencing the desired risky asset share. We identify a range of household level variables which we expect to influence the individual's asset choice, based upon previous empirical work and the preliminary analysis of the data above. The empirical work, for example, Cocco (2005, p554) regressed portfolio share on current labour income, financial net-worth, age, relative real estate and relative mortgage, where "financial net worth is defined as the sum of stocks, bills, and house value less debt". Wachter and Yogo' (2010) regressed on log net-worth, age, marital status. King and Leape (1998) regressed on log net-worth, log net-worth squared, age, age squared, income from employment, education, marital status, and employment status. Hochguertel *et al* (1997) regressed on log financial wealth, age, age squared, employment status and education. Alan *et al.* (2010) regressed on income, wealth, age, education, married with kids, number of children, gender and house ownership. Guariglia (2001) regressed saving ratio on age, age squared, gender, number of children, marital status, education, health status, permanent income and regional dummies. Therefore, in order to be consistent with the existing literature and examine the factors that determine household risky asset shares, we regress portfolio share on a range of variables including net-worth, personal debt, gross house value, outstanding mortgage, income, age, education, employment status, gender, marital status, child and regional dummy variables. In some specifications, we also include health status[22], number of children and permanent income.

In our specifications, we have quadratic terms for net liquid wealth, housing, and age. This is because we expect these explanatory variables have quadratic effect on risky asset share. The key thing is that the quadratic term allows for individuals with different wealth to react differently to changes in the underlying variable and this is something that we wish to investigate since it has policy relevance. For example, if age has non-linear effects then we can think about the impact of an ageing population and so on.

[22] The health status equals to 1, if the individual is reported in excellent health condition; it equals 2 if he/she is in very good health; it equals 3 if he/she is in fair health; it equals 4, if he/she is in poor health; it equals 5, if he/she is in very poor health. In addition, in some specification in my thesis, I also use youngunhealthdum(defined as age<70 and report very poor health condition), oldunhealthdum (defined as age>=70 and report very poor health condition), oldhealthdum(defined as age>=70 and report either in excellent, very good, fair or poor health condition)

The theoretical justification for our chosen explanatory variables is based around the individual's attitude to risk, either via an influence on the risk aversion parameter or through an impact on the habit level of consumption. Therefore, we do not use systematic variation in expectations which can be identified by household specific variables, although behavioural finance proponents might wish to include this as a possible explanation for these household specific effects. We have some points to make in this context when we discuss our results in section 3.4.

We use a standard Tobit model because substantial censoring occurs in the explanatory variables, α*2000* as we have already observed in terms of households which hold no risky assets. We also have to recognise the possibility of right-hand censoring and note that 200 households which report 100% risky asset holding may be subject to this. In terms of demand of the risky assets, individuals who are risk lover can borrow at risk-free rate and invest all in risky assets, which would lead to the risky asset share greater than 1. However, this is not observable[23]. Previous studies used an Ordinary Least Squares regression with the risky asset proportion of wealth as a dependent variable (Gomes and Michaelides, 2005; Friend and Blume, 1975; Morin and Suarez, 1983; Schooley and Worden, 1996) but in so doing are unable to handle the censored observations.

[23] The risky asset share in this thesis is defined as amount of risky assets holdings divided by total amount of risky and risk-free asset holdings, which means the risky asset share, α, satisfies $0 \leqslant \alpha \leqslant 1$, and this is observable. Now, suppose there is an individual, who invests all his money in risky assets, so his risky asset share is 1, as we observe. But his actual demand for risky asset may be greater. If he is allowed to borrow at risk free rate, then his risky asset share could be: risky asset holdings/(risky asset holdings + risk-free asset holdings)= £100/[£100+(-£50)]=2, which is greater than 1, but is not observable. So, in theory, α can be greater than 1, but in practice, it is not.

The standard Tobit model (Tobin, 1958) is shown below where y_i^* is a latent variable, x_i is a vector of explanatory variables, and β is a vector of parameters. The random disturbance ε_i is assumed to be normally, independently, and identically distributed. y_i is the observed dependent variable and C is the point of censoring (Hamilton and Wyckoff, 1991, p461).

$$y_i^* = \beta x_i + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2),$$

where

$$y_i = \max\{y_i^*, C\}$$

In our case:

$$\begin{aligned}
\alpha^*_{2000} &= (1-\beta_0)\alpha_{1995} + \beta_1\, \mathit{netliquidwealth}_i + \beta_2 \mathit{netliquidwealthsquared}_i + \\
&\beta_3 \mathit{personaldebt}_i + \beta_4 \mathit{housing}_i + \beta_5 \mathit{housingsquared}_i + \beta_6 \mathit{outstandingmortgage}_i + \\
&\beta_7 \mathit{incomenlw}_i + \beta_8 \mathit{age}_i + \beta_9 \mathit{agesquared}_i + \beta_{10} \mathit{aleveldum}_i + \beta_{11} \mathit{degreedum}_i + \\
&\beta_{12} \mathit{pensiondum}_i + \beta_{13} \mathit{employeedum}_i + \beta_{14} \mathit{selfemployeddum}_i + \beta_{15} \mathit{unemployeddum}_i + \\
&\beta_{16} \mathit{sexdum}_i + \beta_{17} \mathit{maritalstatus}_i + \beta_{18} \mathit{childdum}_i + \beta_{19} \mathit{londondum}_i + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2),
\end{aligned}$$

where

$$\alpha_{2000} = \begin{cases} 0 & \mathit{if}\ \alpha^*_{2000} \le 0 \\ \alpha^*_{2000} & \mathit{if}\ 0 < \alpha^*_{2000} \le 1 \\ 1 & \mathit{if}\ \alpha^*_{2000} > 1 \end{cases}$$

In order to address the specification problem of standard Tobit model, we estimate also the heteroscedastic Tobit model. To round-off our empirical analysis we also estimate the model using censored quantile regression (CQR) which was first developed by Powell (1986) and has been explored by several scholars such as Fitzenberger (1996), Buchinsky and Hahn (1998), and Chernozhukov and Hong (2002). The CQR regression is an extension of least absolute deviations (LAD) estimation methods for more general quantiles (Powell, 1986). "More importantly, the CQR estimator places no requirement on the distribution of the errors and produces consistent estimates in the presence of heteroskedastic errors" (Billett and Xue, 2007, p1829). Unlike OLS or Tobit estimation, which "estimates the effect of independent variables only on the conditional mean of a dependent variable", censored quantile regression can "estimate the effect of independent variables at a variety of points in the conditional distribution of the dependent variable" (Conley and Galenson, 1998, p475). By using censored quartile regression, we can investigate how the impact of different determinants on portfolio share varies across different quantile of the portfolio share distribution.

The censored quantile regression (CQR) we estimate is as follows:

$$
\begin{aligned}
\alpha^{*}_{2000i} = {} & (1-\beta_{\theta 0})\alpha_{1995i} + \beta_{\theta 1}\, netliquidwealth_i + \beta_{\theta 2} netliquidwealthsquared_i + \\
& \beta_{\theta 3} personaldebt_i + \beta_{\theta 4} housing_i + \beta_{\theta 5} housingsquared_i + \beta_{\theta 6} outstandingmortgage_i + \\
& \beta_{\theta 7} incomenlw_i + \beta_{\theta 8} age_i + \beta_{\theta 9} agesquared_i + \beta_{\theta 10} aleveldum_i + \beta_{\theta 11} degreedum_i + \\
& \beta_{\theta 12} pensiondum_i + \beta_{\theta 13} employeedum_i + \beta_{\theta 14} selfemployeddum_i + \beta_{\theta 15} unemployeddum_i + \\
& \beta_{\theta 16} sexdum_i + \beta_{\theta 17} maritalstatus_i + \beta_{\theta 18} childdum_i + \beta_{\theta 19} londondum_i + \varepsilon_{\theta i}\,,
\end{aligned}
$$

$Quantile_{\theta}(\varepsilon_{\theta i} \mid \alpha_{1995i}, netliquidwealth_i, netliquidwealthsquared_i, personaldebt_i, housing_i,$
$housingsquared_i, outstandingmortgage_i, incomenlw_i, age_i, agesquared_i, aleveldum_i, degreedum_i,$
$pensiondum_i, employeedum_i, selfemployeddum_i, unemployeddum_i, sexdum_i, maritalstatus_i, childdum_i,$
$londondum_i) = 0,$
where $\alpha_{2000i} = \max\{\alpha^{*}_{2000i}, 0\}$ and $Quantile_{\theta}(\varepsilon_{\theta i} \mid .)$ is the θ^{th} conditional quantile of the disturbance.

3.3.5 Standard Tobit Results

Table 3. 7: The results of Tobit regression for our sample

Variables	Model 1	Model 2	Model 3
α1995	0.501***	0.487***	0.499***
	(0.04)	(0.04)	(0.04)
Netliquidwealth	0.579***	0.522***	0.542***
	(0.07)	(0.07)	(0.07)
Netliquidwealthsquared	-0.120***	-0.109***	-0.114***
	(0.02)	(0.02)	(0.02)
Personaldebt	1.263***	1.197***	1.395***
	(0.32)	(0.33)	(0.33)
Housing	0.131***	0.119***	
	(0.03)	(0.04)	
Housingsquared	-0.020***	-0.021***	
	(0.01)	(0.01)	
Outstandingmortgage		0.108***	
		(0.04)	
Nethousing			0.071**
			(0.03)
Nethousingsquared			-0.014*
			(0.01)
Grosslabourincome	0.106		
	(0.11)		
Incomenlw		1.10E-04***	1.03E-04**
		(4.03E-05)	(4.03E-05)
Permanentincomenlw			
Age	0.029***	0.034***	0.033***
	(0.01)	(0.01)	(0.01)

Agesquared	-2.47E-04***	-3.02E-04***	-3.05E-04***
	(4.91E-05)	(5.50E-05)	(5.52E-05)
Aleveldum		0.043	0.054
		(0.03)	(0.03)
Degreedum		0.074*	0.097**
		(0.04)	(0.04)
Pensiondum	0.046	0.034	0.055
	(0.03)	(0.04)	(0.04)
Employeedum		-0.098*	-0.103*
		(0.06)	(0.06)
Selfemployeddum		-0.167**	-0.149**
		(0.07)	(0.07)
Unemployeddum		-0.200**	-0.214***
		(0.08)	(0.08)
Sexdum	0.027	0.035	0.026
	(0.03)	(0.03)	(0.03)
Maritaldum	0.004	-0.010	0.015
	(0.03)	(0.03)	(0.03)
Childdum	0.095***	0.079**	0.097**
	(0.04)	(0.04)	(0.04)
Londondum	-0.012	-0.016	0.002
	(0.05)	(0.05)	(0.05)
Constant	-1.071***	-1.068***	-0.995***
	(0.13)	(0.14)	(0.14)
Log likelihood	-1989.510	-1748.969	-1758.580
LR chi2	554.20	509.66	490.43
Pro>chi2	0	0	0
Pseudo R2	0.1223	0.1272	0.1224
No. of observations	2484	2203	2203
Left-censored observations at α2000<=0	1101	957	957
Uncensored observations	1183	1072	1072
Right-censored observations at α2000>=1	200	174	174

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage and Nethousing are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared, Housingsquared and Nethousingsquared are the squared terms for Netliquidwealth ,Housing and Nethousing which are measured in £100,000 respectively.*

Table 3.7 reports the results of the standard Tobit regression using maximum likelihood methods. We note that previous portfolio share in investment (α_{1995}) has a positive impact on the portfolio share invested in risky assets in 2000 as expected from the partial adjustment model, although the parameter indicates quite slow adjustment to the desired portfolio share. Other factors are shown in the table, namely net liquid wealth, personal debt, housing value, outstanding mortgage loan, the ratio of income to net liquid wealth, age, education level, whether participating in pension schemes, employment status, gender, marital status, whether having children in the family and the London dummy. Table 3.7 reveals an inverted-U shape impact of net liquid wealth on portfolio allocation. In addition, as there are only 10 out of 2484 observations whose net liquid wealth are above the turning point of £239K, it implies that the effect can be simplified to a positive relationship between portfolio share and wealth except for the very wealthy. This positive relationship between portfolio share and wealth is also found in the analysis of Wachter and Yogo (2010).

The risky asset shares follow a hump-shaped pattern in response to variation in housing wealth, with a peak when the net housing value is about £245K. If the net housing value is below £245K, risky asset shares increase in net housing value. If the net housing value is above £245K, risky asset shares decrease in net housing value. Due to missing data for the variable of outstanding mortgage, there are 2408 observations for the variable *OUTSTANDINGMORTGAGE as* well as *NETHOUSING*. Among these observations, 2296 observations are living in a property that has net housing value less than £245K, which implies that for the majority, roughly 95 percent of the sample, their risky asset shares increase in net housing value. The higher net value of their houses, the higher proportion of their wealth would be invested in risky assets. This is consistent with the result observed for liquid wealth above.

Gross housing value also influences households' asset allocation decisions. It has an inverse U-shape of impact on risky asset shares. Roughly 96 percent of the respondents in our sample (i.e.:2375 out of 2484) are living in a property that worth less than the threshold of £282K. As gross house value increases, the risky asset share increases, but at a decreasing rate. This inverse-U shape impact of gross house value on risky asset shares can be explained by the overall effect from three sub-effects, namely, the negative house price risk, the negative housing consumption commitment effect and positive housing wealth effect, which we have detailed in the literature survey (chapter 2.7.1).That means if the property is worth less than the threshold of £282K, the positive housing wealth effect dominants. The house value will provide financial security and encourage the households to invest in risky assets. In contrast, if the property worth is more than the threshold of £282K, the negative house price risk and the negative housing consumption commitment effect dominant.

As the ratio of gross income to liquid wealth rises the individual's risky asset share will increase. This positive impact of the ratio of labour income to net liquid wealth implies that as households have more income relative to their wealth they are in a better position to meet habit level consumption or respond to really bad economic shocks. Hence they can hold a more risky portfolio.

It has also been found that age has an inverse-U shape relationship with risky asset shares with the age of 56 being the turning point. This hump-shaped pattern in age is also consistent with findings in Ameriks and Zeldes (2004) and Wachter and Yogo

(2010). The positive relationship between age and risky-asset share could be explained by risk aversion or through habit. In other words as individuals age their habit level of consumption does not grow as quickly as their income and hence risk aversion declines.

Increasing education attainment increases the risky asset share whereas participation in a pension scheme, no matter whether occupational pension schemes or individual pension schemes, is not statistically significant.

Employment status also affects risky asset shares. The unemployed have the least proportion of investment in risky assets. The self-employed have the second least. It seems likely that such an effect comes from the effect that these two employment states have on the probability of falling close to habit level of consumption with the consequent rise in risk aversion. The base group, the retirees have the highest risky asset shares and this leaves the employees' risky asset shares being the second highest. This may be due to that compared with labour income, the annuity income received by the retirees is more certain and not correlated with the economic environment, hence the retirees is least risk averse.

Gender is not significant in determining asset choice which is inconsistent with the current literature which suggests that "women are indeed more risk-averse than men" (Croson and Gneezy, 2009, p1). Croson and Gneezy (2004) stated that gender differences in preferences were found in many experimental psychology studies.

Marital status has no significant effect while the presence of children does link positively to risky asset holding. Finally the regional (London) dummy is insignificant.

3.3.6 Diagnostic tests and heteroscedastic Tobit regression results

Greene (2008) argued that the standard Tobit model may suffer from inconsistent estimates in the presence of either heteroscedasticity or non-normality in the error terms. By conducting a Lagrange multiplier test (LM test) of normality based on generalized residuals (Chesher and Irish, 1987), we find the hypothesis of normally distributed error is rejected at a normal significance levels. Then we conduct the conditional moment test (Pagan and Vella,1989) to test whether the disturbances in the model are homoscedastic or not. The test results suggest that the null hypothesis of homoskedsticity is also rejected for the standard Tobit model. Therefore, the estimation results in Table 3.7 may be inconsistent.

Another way to test whether heteroscedasticity emerges in our Tobit model is to estimate the restricted model and unrestricted model first and then calculate the likelihood ratio statistics (Greene, 2008). If we can reject the null hypothesis then the errors are not homoscedastic, and we need to interpret the results in the heteroscedastic Tobit model.

Hence, now we first estimate the restricted model where we assume that the errors are homoscedastic. As we can see from Table 3.8, in the homoscedastic Tobit regression, we regress the same explanatory variables as we regressed in Model 2 of Table 3.7.

The difference between a homoscedastic and heteroscedastic Tobit model is that in the homoscedastic Tobit model the variance of the regression error, (ε_i), is homoscedastic whereas in the heteroscedastic Tobit model the variance of the regression error (ε_i), is heteroscedastic. In other words, in the homoscedastic Tobit model, $E(\varepsilon_i^2) = \sigma^2$.In the heteroscedastic Tobit model, we assume the variance of the regression error can be specified as a function of variables:

$$E(\varepsilon_i^2) = \sigma_i^2 = \sigma^2 \exp(Z_i^{'}\gamma)$$

where $Z_i^{'}$ is a row vector and Z_i refers to the individual *i*'s *ALLOCATION*1995 (α_{1995}), *NETLIQUIDWEALTH, NETLIQUIDWEALTHSQUARED, PERSONALDEBT, HOUSING, HOUSINGSQUARED, OUTSTANDINGMORTGAGE, INCOMENLW, AGE, AGESQUARED, ALEVELDUM, DEGREEDUM, PENSIONDUM, EMPLOYEEDUM, SELFEMPLOYEDDUM, UNEMPLOYEDDUM, SEXDUM, MORITALDUM, CHILDDUM* and *LONDONDUM;* where γ is a column vector and refers to the corresponding coefficients for Z_i.

As can be seem from Table 3.8, the log likelihood for the restricted model and unrestricted model is -1749 and -1678 respectively. Our null hypothesis is that the errors are homoscedastic, in other words, we test whether γ=0 or not. The likelihood statistic is -2[-1749-(-1678)]=142. This statistic follows a limiting chi-squared distribution with 20 degrees of freedom which implies a critical value of 38. Thus, we reject the null hypothesis and conclude that the errors are heteroscedastic. We report the results of estimating our model with heteroscedastic corrected standard errors in Table 3.8.

Table 3. 8: Homoscedastic Tobit model and heteroscedastic Tobit model

Variables	Homoscedastic coefficient	Heteroscedastic coefficient	$\boxed{\gamma}$
α1995	0.487***	0.445***	-0.087
	(0.04)	(0.04)	(0.13)
Netliquidwealth	0.522 ***	0.731***	-1.782***
	(0.07)	(0.10)	(0.26)
Netliquidwealthsquared	-0.109 ***	-0.293***	0.669***
	(0.02)	(0.06)	(0.13)
Personaldebt	1.197 ***	1.234***	-1.806
	(0.33)	(0.27)	(1.26)
Housing	0.119 ***	0.151***	-0.467***
	(0.04)	(0.04)	(0.14)
Housingsquared	-0.021 ***	-0.027***	0.066**
	(0.01)	(0.01)	(0.03)
Outstandingmortgage	0.108 ***	0.142***	0.257*
	(0.04)	(0.04)	(0.13)
Incomenlw	1.10E-04***	1.93E-04	3.17E-04
	(4.03E-05)	(1.38E-04)	(3.39E-04)
Age	0.034 ***	0.037***	-0.03
	(0.01)	(0.01)	(0.02)
Agesquared	-3.02E-04***	-3.24E-04***	2.55E-04
	(5.50E-05)	(4.60E-05)	(2.03E-04)
Aleveldum	0.043	0.016	-0.037
	(0.03)	(0.03)	(0.11)
Degreedum	0.074 *	0.078**	-0.318**
	(0.04)	(0.04)	(0.14)
Pensiondum	0.034	0.086**	-0.286**
	(0.04)	(0.04)	(0.13)
Employeedum	-0.098 *	-0.124**	0.119
	(0.06)	(0.06)	(0.2)
Selfemployeddum	-0.167 **	-0.161***	-0.164
	(0.07)	(0.06)	(0.23)
Unemployedum	-0.200 **	-0.217**	0.149
	(0.08)	(0.10)	(0.32)
Sexdum	0.035	-0.008	0.188*
	(0.03)	(0.03)	(0.1)
Maritaldum	-0.010	-0.034	0.099
	(0.03)	(0.03)	(0.12)
Childdum	0.079 **	0.064	0.068
	(0.04)	(0.04)	(0.14)

Londondum	-0.016	-0.049	-0.044
	(0.05)	(0.04)	(0.16)
Constant	-1.068***	-1.186***	
	(0.14)	(0.17)	
Log likelihood	-1749	-1678	
No. of observations	2203	2203	
Left-censored observations at α2000<=0	957	957	
Uncensored observations	1072	1072	
Right-censored observations at α2000>=1	174	174	

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 3.8 suggests that the coefficient estimates in the heteroscedastic Tobit model have the same sign as in the homoscedastic Tobit model and values are similar across the two estimations, for example, the coefficients on *PERSONALDEBT*, *HOUSING, HOUSINGSQUARED, AGE* and *AGESQUARED*. However, risky asset shares in 1995 have less of an effect on risky asset shares in 2000. The net liquid wealth still has an inverse U-shape effect, but the turning point is £122K rather than £239K as in the homoscedastic model. Because there are only 1.8 percent of respondents (i.e.:39 out of 2203 respondents) who have more than £122K net liquid wealth, we can still simplify the inverse-U shape effect as a positive relationship between risky asset share and individual's net liquid wealth.

The outstanding mortgage has a larger effect. The effect from the ratio of income to net liquid wealth is not statistically significant under the heteroscedastic model. The effect of receiving higher education increases slightly. Of significance we note that the coefficient for *PENSIONDUM* is more than tripled and it is statistically significant from zero at the 5% significance level. We can also observe that the effects of employment status are relatively the same under homoscedastic model and herteroscedastic model, however, the effect becomes more significant under heteroscedastic estimation. Overall the results are similar with some variation and we will explain this in more details when we interpret these results in section 3.4.

3.3.7 CQR model and results

To provide a further perspective on the empirical analysis of our dataset, we analyze the empirical model using a censored quantile regression. This estimator is confirmed to "remain consistent and asymptotically normal for a wide class of error distributions and be robust to heteroscedasticity" (Powell, 1986; Billett and Xue, 2007, p1841). Unlike OLS or Tobit estimation, which considers the conditional mean, censored quantile regression estimates the effect of explanatory variables at different quantiles of the distribution of the error term. By using censored quantile regression, we also control for the censored nature of our observations of the dependent variable.

Our quantile regression mode can be written as:

$$\alpha^*_{2000i} = (1-\beta_{\theta 0})\alpha_{1995i} + \beta_{\theta 1}\ netliquidwealth_i + \beta_{\theta 2} netliquidwealthsquared_i +$$

$$\beta_{\theta 3} personaldebt_i + \beta_{\theta 4} housing_i + \beta_{\theta 5} housingsquared_i + \beta_{\theta 6} outstandingmortgage_i +$$

$$\beta_{\theta 7} incomenlw_i + \beta_{\theta 8} age_i + \beta_{\theta 9} agesquared_i + \beta_{\theta 10} aleveldum_i + \beta_{\theta 11} degreedum_i +$$

$$\beta_{\theta 12} pensiondum_i + \beta_{\theta 13} employeedum_i + \beta_{\theta 14} selfemployeddum_i + \beta_{\theta 15} unemployeddum_i +$$

$$\beta_{\theta 16} sexdum_i + \beta_{\theta 17} maritalstatus_i + \beta_{\theta 18} childdum_i + \beta_{\theta 19} londondum_i + \varepsilon_{\theta i},$$

$$Quantile_\theta(\varepsilon_{\theta i} \mid \alpha_{1995i}, netliquidwealth_i, netliquidwealthsquared_i, personaldebt_i, housing_i,$$
$$housingsquared_i, outstandingmortgage_i, incomenlw_i, age_i, agesquared_i, aleveldum_i, degreedum_i,$$
$$pensiondum_i, employeedum_i, selfemployeddum_i, unemployeddum_i, sexdum_i, maritalstatus_i, childdum_i,$$
$$londondum_i) = 0,$$

where $\alpha_{2000i} = \max\{\alpha^*_{2000i}, 0\}$.

and $Quantile_\theta(\varepsilon_{\theta i} \mid .)$ is the θ^{th} conditional quantile of the disturbance.

The results for a standard Tobit model and CQR models are reported in Table 3.9 and Table 3.10, while a summary of the CQR results are presented in Figure 3.3-3.6. Because we have 20 independent variables and one intercept, hence we have 21 plots in Figure 3.3-3.6, in other words, each plot depicts one coefficient in the CQR model. In each plot, the darker solid curve represents the 9 distinct censored quantile regression estimates for quantile ranging from 0.1 to 0.9. These point estimates measure the impact of a one-unit change of the independent variable on risky asset allocation while keeping the value of other independent variables constant. The horizontal axis of each plot is the different quantiles and the vertical axis is the covariate effect. The lighter solid line describes the estimates from the Tobit model which indicate the impact on the conditional mean. The two dark dotted curves represent 95% confidence intervals for the censored quantile regression estimates. The two light dotted lines depict 95% confidence intervals for the standard Tobit regression estimates.

Table 3. 9: Estimation results for standard Tobit model and CQR models

	Coefficients				
Variables	**Tobit**	**Quantile 0.1**	**Quantile 0.2**	**Quantile 0.3**	**Quantile 0.4**
α1995	0.487***	0.472**	0.588***	0.271***	0.281***
	(0.04)	(0.22)	(0.06)	(0.03)	(0.03)
Netliquidwealth	0.522***	2.028***	1.514***	1.692***	0.919***
	(0.07)	(0.66)	(0.13)	(0.12)	(0.06)
Netliquidwealthsquared	-0.109***	-1.813***	-0.919***	-1.223***	-0.295***
	(0.02)	(0.66)	(0.09)	(0.10)	(0.03)
Personaldebt	1.197***	3.200***	2.382***	2.245***	1.315***
	(0.33)	(0.82)	(0.21)	(0.21)	(0.20)
Housing	0.119***	0.227	0.153***	0.134***	0.055*
	(0.04)	(0.24)	-0.04	(0.03)	(0.03)
Housingsquared	-0.021***	-0.067	-0.047***	-0.039***	-0.012*
	(0.01)	(0.05)	(0.01)	(0.01)	(0.01)
Outstandingmortgage	0.108***	0.121**	0.111***	0.082***	0.079***
	(0.04)	(0.05)	(0.02)	(0.03)	(0.03)
Incomenlw	1.10E-04***	1.16E-04***	9.28E-05***	8.46E-05***	7.81E-05***
	(4.03E-05)	(2.64E-05)	(5.31E-06)	(1.01E-05)	(1.19E-05)
Age	0.034***	0.017	0.030***	0.028***	0.019***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Agesquared	-3.02E-04***	-1.28E-04	-2.57E-04***	-2.78E-04***	-1.75E-04***
	(5.50E-05)	(1.97E-04)	(7.23E-05)	(5.76E-05)	(5.32E-05)
Aleveldum	0.043	0.057	-0.052	-0.021	0.034
	(0.03)	(0.11)	(0.03)	(0.02)	(0.03)
Degreedum	0.074*	0.038	0.038	0.043	0.066**
	(0.04)	(0.15)	(0.03)	(0.03)	(0.03)
Pensiondum	0.034	0.129	0.073*	-0.011	0.015

	(0.04)	(0.10)	(0.04)	(0.03)	(0.03)
Employeedum	-0.098*	-0.119	-0.068	0.014	-0.097**
	(0.06)	(0.16)	(0.05)	(0.04)	(0.05)
Selfemployeddum	-0.167**	-0.267*	-0.258***	-0.078	-0.177***
	(0.07)	(0.15)	(0.06)	(0.05)	(0.05)
Unemployeddum	-0.200**	0.564***	-0.048	-0.010	-0.227**
	(0.08)	(0.21)	(0.07)	(0.06)	(0.10)
Sexdum	0.035	0.033	0.092***	0.035*	-0.000
	(0.03)	(0.10)	(0.03)	(0.02)	(0.02)
Maritaldum	-0.010	-0.061	-0.141***	-0.078***	-0.052**
	(0.03)	(0.10)	(0.03)	(0.02)	(0.03)
Childdum	0.079**	0.048	0.090**	0.080***	0.068**
	(0.04)	(0.16)	(0.04)	(0.03)	(0.03)
Londondum	-0.016	-0.121	0.006	-0.051	-0.110***
	(0.05)	(0.11)	(0.04)	(0.03)	(0.04)
Constant	-1.068***	-1.393	-1.549***	-1.028***	-0.595***
	(0.14)	(0.89)	(0.22)	(0.16)	(0.16)
Pseudo R2	0.1272	0.1938	0.1463	0.1337	0.1094
No. of observations	2203	205	348	607	959

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 3. 10: Estimation results for standard Tobit model and CQR models

	Coefficients					
Variables	**Tobit**	**Quantile 0.5**	**Quantile 0.6**	**Quantile 0.7**	**Quantile 0.8**	**Quantile 0.9**
α1995	0.487***	0.395***	0.550***	0.609***	0.493***	0.194***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Netliquidwealth	0.522***	0.677***	0.510***	0.415***	0.236***	0.054
	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.07)
Netliquidwealthsquared	-0.109***	-0.149***	-0.100***	-0.083***	-0.047	-0.014
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Personaldebt	1.197***	1.026***	0.869***	0.779***	0.809**	0.389*
	(0.33)	(0.26)	(0.30)	(0.28)	(0.36)	(0.23)
Housing	0.119***	0.078**	0.095***	0.107***	0.032	-0.012
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)
Housingsquared	-0.021***	-0.017**	-0.019**	-0.026***	-0.010	-0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Outstandingmortgage	0.108***	0.083**	0.072**	0.102***	0.162***	0.144***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
Incomenlw	1.10E-04***	5.92E-05***	5.11E-05***	4.55E-05**	8.65E-05***	4.73E-05***
	(4.03E-05)	(1.55E-05)	(1.84E-05)	(1.99E-05)	(2.37E-05)	(1.13E-05)
Age	0.034***	0.014**	0.016***	0.022***	0.037***	0.017***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Agesquared	-3.02E-04***	-1.39E-04**	-1.64E-04***	-2.08E-04***	-3.35E-04***	-1.32E-04***
	(5.50E-05)	(5.85E-05)	(5.92E-05)	(5.26E-05)	(5.38E-05)	(4.82E-05)
Aleveldum	0.043	-0.010	-0.010	0.006	0.039	-0.006
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
Degreedum	0.074*	0.003	0.007	0.028	0.019	-0.034
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)

Pensiondum	0.034	0.039	0.025	0.046	0.002	0.009
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)
Employeedum	-0.098*	-0.072	-0.081	-0.052	-0.097	-0.042
	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)	(0.05)
Selfemployeddum	-0.167**	-0.142**	-0.109*	-0.083	-0.197***	-0.157**
	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)	(0.06)
Unemployeddum	-0.200**	-0.109	-0.136	-0.069	-0.188**	-0.163**
	(0.08)	(0.09)	(0.10)	(0.07)	(0.08)	(0.07)
Sexdum	0.035	0.057**	0.041	0.052**	0.052*	0.054**
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Maritaldum	-0.010	0.008	-0.022	-0.004	0.020	-0.002
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Childdum	0.079**	0.009	0.046	0.091***	0.085**	0.047
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
Londondum	-0.016	-0.048	-0.048	-0.022	0.020	0.004
	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)
Constant	-1.068***	-0.425***	-0.385**	-0.548***	-0.577***	0.297**
	(0.14)	(0.16)	(0.16)	(0.13)	(0.13)	(0.12)
Pseudo R2	0.1272	0.1227	0.1589	0.1733	0.1469	0.0393
No. of observations	2203	1305	1643	1942	2185	2203

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £100,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Figure 3. 3: Standard Tobit and Censored Quantile Regression Estimates for risky asset allocation

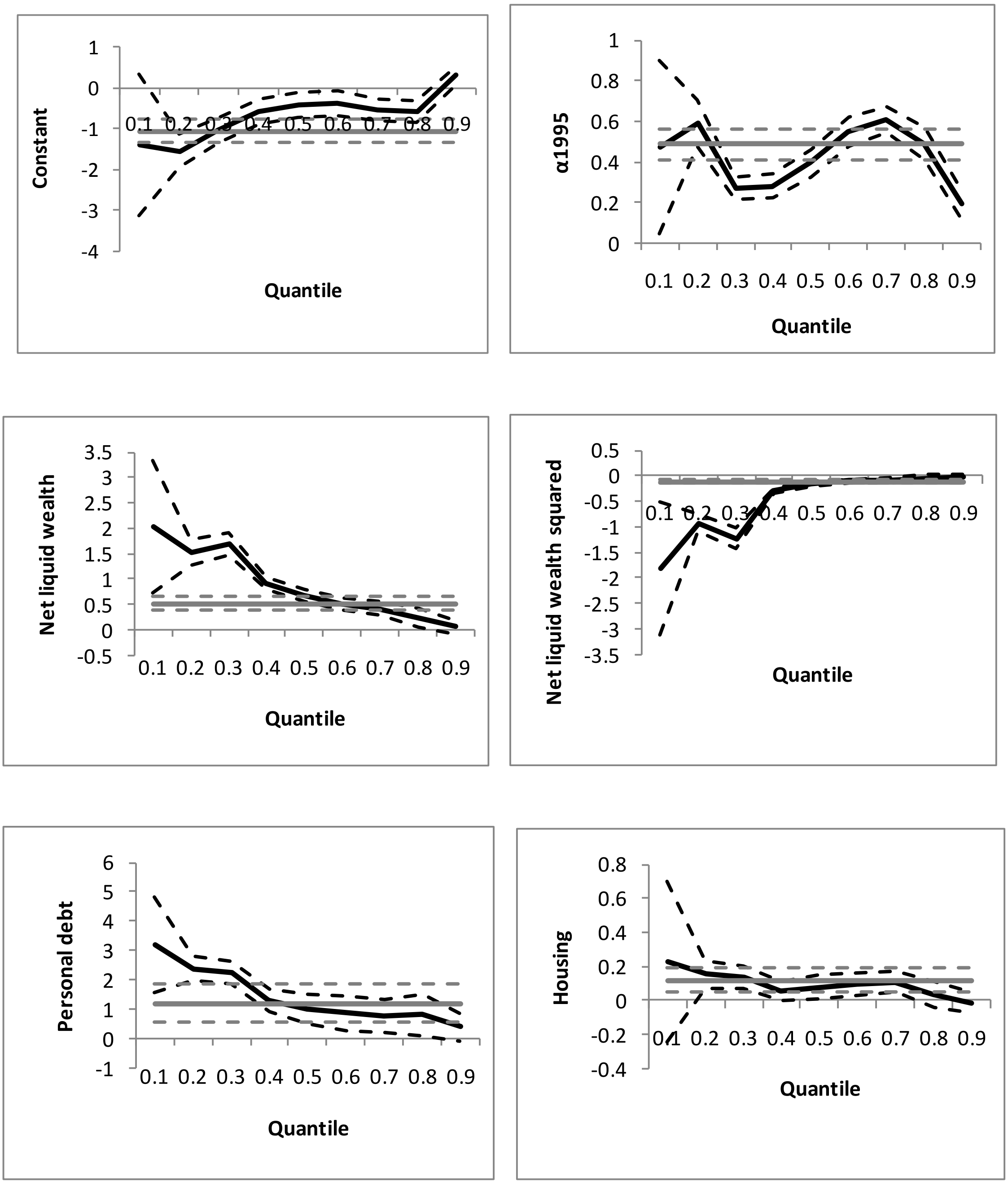


Figure 3. 4:Standard Tobit and Censored Quantile Regression Estimates for risky asset allocation

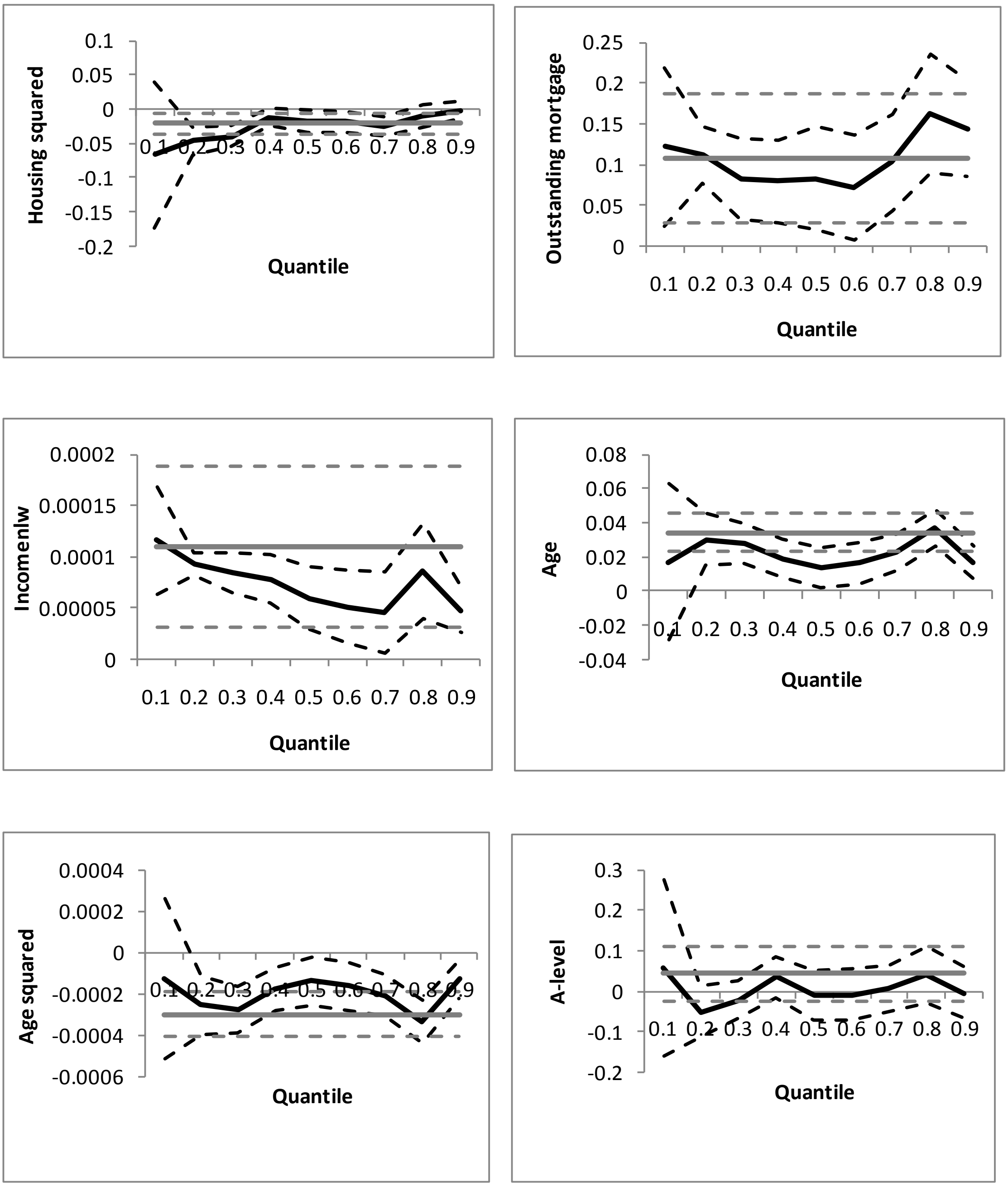


Figure 3. 5:Standard Tobit and Censored Quantile Regression Estimates for risky asset allocation

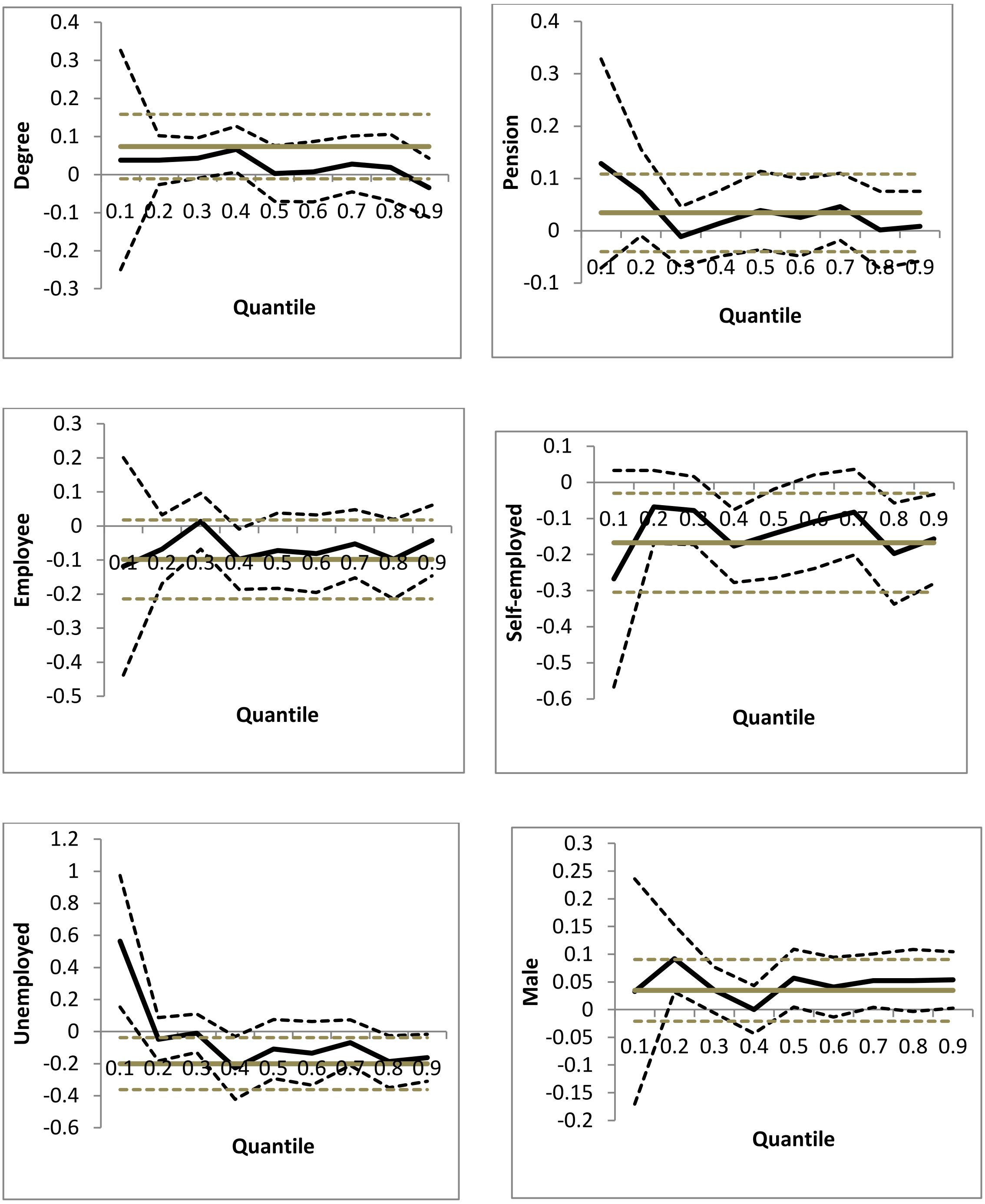
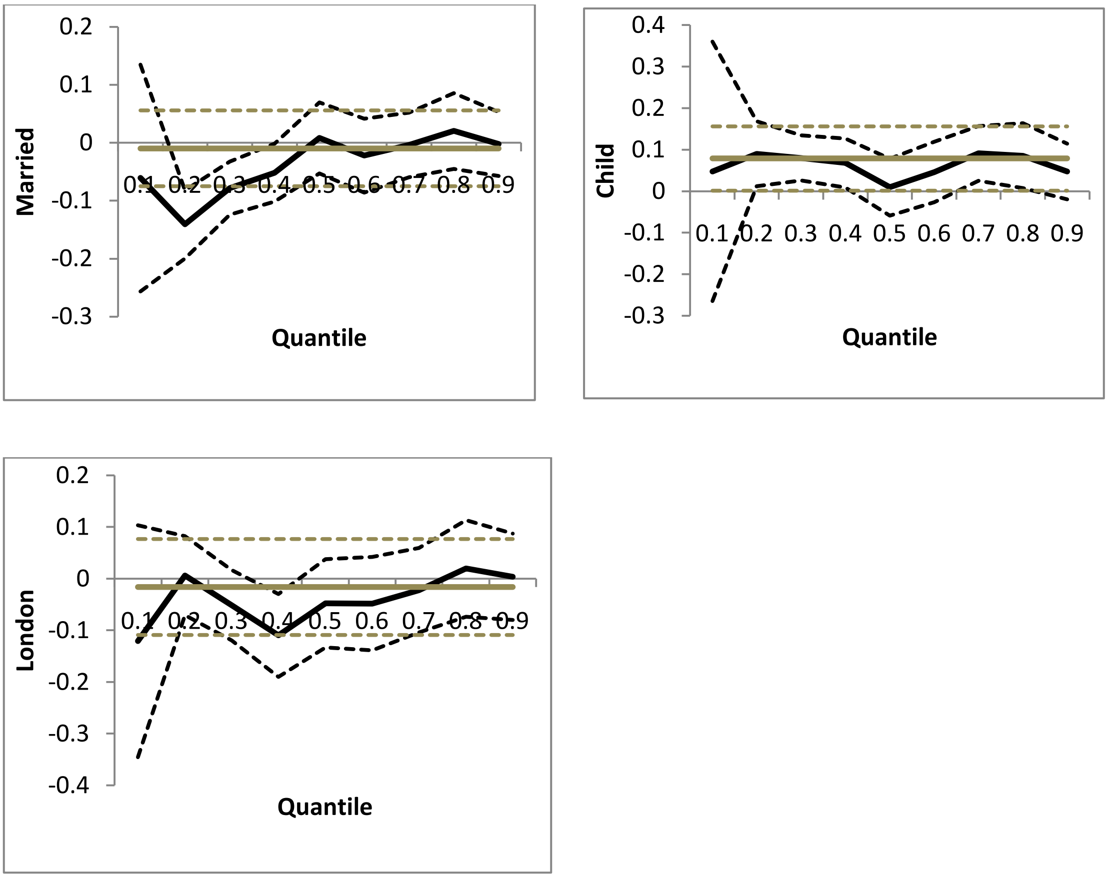


Figure 3. 6:Standard Tobit and Censored Quantile Regression Estimates for risky asset allocation



We discuss different behaviour across the quantiles that is revealed by the parameter estimates. Note that a key aspect of the analysis is to identify those departures of the quantile coefficients from the conditional mean levels which are significant. Thus, in the top right panel of Figure 3.3, we can see that the mean effect of the lagged risky asset share (*allocation1995)*, on current risky asset share is 0.5. The results from censored quantile regression indicate that this parameter varies significantly according to quantile. Broadly we can identify a smaller adjustment parameter in lower quantiles while the effect is significantly larger in the upper quantiles.

Net liquid wealth has a clearly asymmetric impact according to which quantile we are investigating. We observe that the impact declines significantly as we move to higher quantiles. The non-linear aspect of this relationship is also markedly different at the lower quantiles. In the lower quantiles, for example, at the 0.1, 0.2, 0.3 and 0.4 quantile of the conditional distribution, the net liquid wealth maximizes its effect on individual's risky asset share when the net liquid wealth approximately equals to £56,000, £82,000, £69,000 and £156,000 respectively[24]. When we look at the higher quantiles, the optimal point would be reached if the net liquid wealth is equal to a higher value, for example, at the 0.8 quantile the risky asset share is increasing if net liquid wealth increases from negative value to £250,000, and it falls as if the value of net liquid wealth is beyond £250,000. These findings may suggest that if we want to encourage individuals to invest a higher proportion of wealth in risky assets, then we may focus on increasing net liquid wealth of the individuals who are in the lower quantile of the conditional distribution of risky asset shares, because one unit increase in

[24] We can calculate it by using the coefficient of netliquidwealth and netliquidwealthsquared..

the net liquid wealth would have a larger impact on risky asset shares of individuals in the lower quantiles than risky asset shares of individuals in the higher quantiles.

Housing wealth also has a significant differential impact according to the quantile examined. However, this is limited to the lowest and highest quantiles. It has a quadratic effect on household's risky asset shares. In the lower quantiles, for example, at the 0.3 quantile, the gross housing effect increases as the housing value increases from zero to £170,000 and the effect starts to decrease as the housing value is above £170,000. In the higher quantiles, the housing effect peaks at a higher housing value. For example, at the 0.7 quantile, the housing effect reaches its maximum point when the value of the house exceeds £210,000. In comparison, the result of Tobit model suggests that the peak point is £282,085, which is much higher than the optimal points under the censored quantile regressions.

The outstanding mortgage loan has positive impact on risky assets shares, as we can see from the top right panel of Figure 2 (b). If the total amount of outstanding mortgage increases by £100,000, then at the 0.3, 0.4, 0.5, and 0.6 quantile of the conditional distribution, the individual' risky asset share would increase by roughly 8 percent in point, whereas at the 0.8 and 0.9 quantile of the conditional distribution, the individual's risky asset share would increase by 16 percent in point and 14 percent in point respectively. This disparity could not be revealed by the Tobit model. The result from Tobit model estimated the mean effect of increasing outstanding mortgage loan by £100,000 is 11 percent point increase in individual's risky asset share.

The income-to -wealth ratio also exhibits differential significant impacts across quantiles. Generally we see a smaller positive impact in the middle quantiles. For the middle quantiles we observe that age has a differential non-linear impact. Unemployment has significant differential impacts in the lowest 4 quantiles. Apart from these effects we do not see a particularly clear differential response across the quantiles.

3.3.8 Marginal effects and Robustness

This section provides robustness tests for the main specifications we estimated in the section 3.3.5.

The model 1 in the following Table 3.11 is our main specification, which is regressed on the same explanatory variables as model 2 in Table 3.7, Homoscedastic model in Table 3.8, Tobit model in Table 3.9 and Tobit model in Table 3.10. The interpretation of the results is, therefore, the same.

The marginal effects after Tobit regression are also reported Table 3.11. The marginal effects measure the expected change in risky asset share as a function of one unit increase in the explanatory variable. The second column presents the value of dy/dx and the third column presents the average value of the explanatory variable. As we can see, an increase of ten percentage point in previous risky asset share ($\alpha 1995$) implies an increase in the proportion of net wealth invested in risky assets by 2.44 percentage point in 2000. In other words, the expected/predicted portfolio share would increase from

26.01 percent[25] to 28.45 percent. Similarly, if average net liquid wealth increases by £100,000, the expected/predicted risky asset share would increase by 20.7 percentage point. An increase of £100,000in personal debt would result in an increase of 60 percentage point in expected risky asset share. An increase of £100,000 in gross house value would result in an increase of 4.9 percentage point in expected risky asset share. If average outstanding mortgage increases by £100,000, the expected portfolio share in risky asset would increase by 5.4 percentage point. The marginal effect of *incomenlw* on risky asset share is close to zero but is positive and significant. An increase of 10 years in average age would increase the expected risky asset share by 15.49 percentage point. Because the marginal effect of the dummy variables is measured in terms of discrete change of dummy variable from 0 to 1, the results in Table 3.11 suggest that an individual whose highest education level is first degree or higher would invest 3.8 percentage point higher than an individual with whose highest education is an O-level or under. Compared with the retirees' risky asset share, the risky asset share of employees is 5 percentage point less; the risky asset share of self-employed people is 7.8 percentage point less; the risky asset share of unemployed people is 9.1 percentage point less. The presence of chid/children increases the risky asset share by 4 percentage point.

We recognise that some of the explanatory variables are potentially endogenous, and this could lead to inconsistent estimators. Therefore, we carry out a two-step procedure (Wooldridge, 2002, p532) to test the exogeneity, and we find that there is evidence that incomenlw is endogenous in the specification. We assume that *incomenlw1995, netliquidwealth, personaldebt, housing, outstandingmortgage, age*,

[25] Please note this predicted portfolio share is not presented in the Table 3.11. It is part of the results we obtain when estimating the marginal effects after Tobit

agesquared, aleveldum, degreedum, pensiondum, employeedum, selfemployeddum, unemployeddum, sexdum, maritaldum, childdum,and londondum are exogenous in the *incomenlw* equation, therefore these are instruments for *incomenlw*. We firstly regress *incomenlw* on these variables and get the residual. Then we run the main tobit specification with this residual, and we find the coefficient for this residual is -0.013 with t statistic equals -1.89. Hence, we regress on *permanentincome* and *permanentincomenlw* in model 2 and 3 in the following Table 3.11, as well as in model 2,3, 6,7 in Table 3.12, in order to test the robustness of our results. In addition, following the two-step procedure, we can not reject other explanatory variables are exogenous. Furthermore, there are some literature which do not handle the endogeneity issue, for example, Wachter and Yogo (2010), and Cocco (2005).

In the fourth column of the following Table 3.11, we present the results for estimating model 2 where we regress on the ratio of permanent income to net liquid wealth (*Permanentincomenlw*) instead of the ratio of labour income to net liquid wealth (*Incomenlw*). We follow Guariglia's (2001) approach to obtain the value of permanent income for individuals whose age is between 21 and 65. We use the BHPS data in 1995 and 2000, and we, firstly, run a random effect model by regressing individuals' gross labour income on "age, age squared, education dummies, occupational dummies, and interactions of the latter two groups of dummies with age and age squared" (Guariglia, 2001, p627). Then we use the estimated coefficients to predict the permanent income for individuals in 1995 and 2000 respectively. Finally, we divide permanent income by net liquid wealth to get the ratio. The reason why we regress on *Permanentincomenlw* is that we recognise gross labour income is potentially endogenous which may lead to inconsistent estimators. The results for this specification are presented in column four.

Because under the current approach, only individuals aged between 21 and 65 can have permanent income, so the sample size is reduced to 1708. For comparison, we set up model 3 which regresses on *Incomenlw* but use the same sample. As we can see, in terms of sign and significance level, there is no difference between model 2 and model 3, although the value of the coefficient is slightly different between these two.

We also carry out a robustness test by deleting the outliers. We delete the 1% tails of all regression variables in model 1 and report the results in the last column of Table 3.11. As a result, the number of observations is reduced from 2203 to 2081. If we compare the results of model 1 and model 4, we find that the results do not change in terms of sign and significance level for variables such as *α1995, Netliquidwealth, Netliquidwealthsquared, Personaldebt, Housing, Housingsquared, Outstandingmortgage, Age , Agesquared* and *Unemployeddum*. The positive effects of *Incomenlw, Degreedum* and *Childdum* which are observed in model 1 are not found in model 4.The negative effect of *Employeedum* are also not found in model 4. The negative effect of *Selfemployedum* becomes less and the significance level is changed from 5 percent to 10 percent.

Table 3. 11: Marginal effects and robustness tests for the main specification

Variables	Model 1	Marginal effects dy/dx	X	Model 2: regress on *Pincomenlw*	Model 3: compare with model 2	Model 4: control for outlier
α1995	0.487***	0.244***	0.278	0.437***	0.438***	0.463***
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Netliquidwealth	0.522***	0.262***	0.134	0.587***	0.583***	1.419***
	(0.07)	(0.04)		(0.09)	(0.09)	(0.15)
Netliquidwealthsquared	-0.109***	-0.055***	0.143	-0.123***	-0.122***	-0.904***
	(0.02)	(0.01)		(0.03)	(0.03)	(0.13)
Personaldebt	1.197***	0.600***	0.015	1.193***	1.188***	1.864***
	(0.33)	(0.17)		(0.33)	(0.33)	(0.51)
Housing	0.119***	0.060***	0.997	0.056	0.060	0.142***
	(0.04)	(0.02)		(0.04)	(0.04)	(0.05)
Housingsquared	-0.021***	-0.011***	1.844	-0.011	-0.012	-0.039***
	(0.01)	(3.95E-03)		(0.01)	(0.01)	(0.01)
Outstandingmortgage	0.108***	0.054***	0.251	0.136***	0.134***	0.173***
	(0.04)	(0.02)		(0.04)	(0.04)	(0.06)
Incomenlw	1.10E-04***	5.51E-05***	28.482		1.04E-04***	-3.00E-04
	(4.03E-05)	(2.00E-05)			(3.98E-05)	(5.78E-04)
Permanentincomenlw				8.03E-05***		
				(2.88E-05)		
Age	0.034***	0.017***	49.988	0.041***	0.041***	0.026***

	(0.01)	(2.83E-03)		(0.01)	(0.01)	(0.01)
Agesquared	-3.02E-04***	-1.51E-04***	2806.470	-3.82E-04***	-3.91E-04***	-2.35E-04***
	(5.50E-05)	(3.00E-05)		(1.37E-04)	(1.37E-04)	(5.53E-05)
Aleveldum	0.043	0.022	0.272	0.031	0.032	0.027
	(0.03)	(0.02)		(0.04)	(0.04)	(0.03)
Degreedum	0.074*	0.038*	0.150	0.074*	0.075*	0.031
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Pensiondum	0.034	0.017	0.473	0.027	0.021	0.015
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Employeedum	-0.098*	-0.050*	0.609	-0.105	-0.105	-0.072
	(0.06)	(0.03)		(0.07)	(0.07)	(0.06)
Selfemployeddum	-0.167**	-0.078***	0.076	-0.166**	-0.157**	-0.137*
	(0.07)	(0.03)		(0.08)	(0.08)	(0.07)
Unemployeddum	-0.200**	-0.091***	0.047	-0.242**	-0.235**	-0.167**
	(0.08)	(0.03)		(0.09)	(0.09)	(0.08)
Sexdum	0.035	0.017	0.497	0.058*	0.058*	0.026
	(0.03)	(0.01)		(0.03)	(0.03)	(0.03)
Maritaldum	-0.010	-0.005	0.619	0.004	0.002	-0.012
	(0.03)	(0.02)		(0.04)	(0.04)	(0.03)
Childdum	0.079**	0.040*	0.200	0.059	0.061	0.066
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Londondum	-0.016	-0.008	0.097	0.012	0.010	-0.009
	(0.05)	(0.02)		(0.05)	(0.05)	(0.05)

Constant	-1.068***	-1.152***	-1.165***	-0.917***
	(0.14)	(0.22)	(0.22)	(0.15)
Log likelihood	-1748.969	-1351.224	-1350.791	-1617.480
LR chi2	509.66	380.63	381.50	497.64
Pro>chi2	0	0	0	0
Pseudo R2	0.1272	0.1235	0.1237	0.1333
No. of observations	2203	1708	1708	2081
Left-censored observations at α2000<=0	957	737	737	913
Uncensored observations	1072	846	846	1015
Right-censored observations at α2000>=1	174	125	125	153

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

The following Table 3.12 consists two parts. The first part is comprised of model 1 to model 4 which are all Tobit regressions. The second part is comprised of model 5 to model 8 which are all Probit regressions. The difference between these four Tobit regressions and the previous main specification in Table 3.11 is that in these four Tobit regressions we include variable on gross labour income, variables on the number of children aged below 15 in the family and variables on the health of the individual[26].

As we can see, compared with the main specification (model 1 in Table 3.11), the results in model 1 of Table 3.12 do not change in terms of sign and significance level for variables such as *α1995, Netliquidwealth, Netliquidwealthsquared,, Personaldebt, Housing, Housingsquared, Outstandingmortgage, Incomenlw, Age , Agesquared, Degreedum,Selfemployeddum,Unemployeddum* and *Childdum.* Only the coefficient for *Employeedum* becomes statistically insignificant.

In model 2 of Table 3.12, we regress on *Permanentincome and Permanentincomenlw* instead of *Grosslabourincome* and *Incomenlw*. Because only individuals aged between 21 and 65 can have permanent income, the sample size is reduced to 1708. For comparison, we set up model 3 which regresses on *Grosslabourincome* and *Incomenlw* but use the same sample. The Table 3.12 suggests that in terms of sign and significance level, there is no much difference between model 2 and model 3, except that in model 2 the coefficients of *Degreedum* and *Sexdum* are not statistically significant

[26] The health status equals to 1, if the individual is reported in excellent health condition; it equals 2 if he/she is in very good health; it equals 3 if he/she is in fair health; it equals 4, if he/she is in poor health; it equals 5, if he/she is in very poor health. In addition, in some specification in my thesis, I also use youngunhealthdum(defined as age<70 and report very poor health condition), oldunhealthdum (defined as age>=70 and report very poor health condition), oldhealthdum(defined as age>=70 and report either in excellent, very good, fair or poor health condition)

We also carry out a robustness test by controlling for outliers. We delete the 1% tails of all regression variables in model 1 and report the results in column four of Table 5.12. Therefore, the number of observations is reduced from 2203 to 2057. If we compare the results of model 1 and model 4, we find that the results do not change in terms of sign and significance level for most variables, except that the positive effects of *Incomenlw*, *Degreedum* and *Childdum* which are observed in model 1 are not found in model 4.

In addition to the Tobit regressions, from model 5 to model 8 in Table 3.12 we report some Probit regressions to examine the factors which determine the probability of an individual investing in risky assets. Similar to the Tobit regressions in Table 3.12, the Probit regressions also include variable on gross labour income, variables on the number of children aged below 15 in the family and variables on the health of the individual.

As we can see from the results of these four Probit regressions, previous participation in holding risky assets (*Participation1995*) has a big impact on the participation in 2000. The coefficient of *Participation1995* is 0.992, 0.920, 0.918 and 1.000 in model 5 to model 8 respectively, which is statistically significant. The net liquid wealth has inverse-U shape of impact on participation and personal debt has a positive impact, both of which are consistent with the findings in Tobit regressions. Although the results in model 5 suggests the non-linear impact of gross house value on probability of an individual investing in risky assets, only positive impact has been found in model 6, 7 and 8. The positive impact of outstanding mortgage has also been found in model 8 where we control for outliers. In model 6 we regress on *Permanentincome* and *Permanentincomenlw*, and we find permanent income has a positive impact on the probability of holding risky assets. Consistent with the findings in Tobit regressions, the impact of age is inverse-U shape and the impact of unemployment (*unemployeddum*) is negative in Probit regressions. The results in model 5 of Table 3.12 also suggest that an individual whose highest education level is first degree or higher have a higher probability of investing in risky assets than an individual whose highest education is an O-level or under have. This positive impact has also been found in model 7 in which all the individuals are aged between 21 and 65. The results in model 6 and model 7 suggest that the number of kids in the family have an negative impact on probability of investing in risky assets. The results in model 5 and model 8 suggest that compared with individuals who are young and healthy, individuals who are old and unhealthy have much less probability in investing in risky assets. The coefficient of *oldunhealthdum* is -1.147 and -1.277 in model 5 and model 8 respectively.

Table 3. 12: Robustness tests for other specifications which include number of kids and health status

Variables	Model 1 Tobit	Model 2: regress on *pincome, pincomenlw*	Model 3: compare with model 2	Model4: control for outliers Tobit	Model 5 Probit	Model 6 : regress on *pincome, pincomenlw*	Model 7: compare with model 6	Model 8: control for outliers Probit
α1995	0.491***	0.443***	0.442***	0.476***				
	(0.04)	(0.04)	(0.04)	(0.04)				
Participation1995					0.992***	0.920***	0.918***	1.000***
					(0.06)	(0.07)	(0.07)	(0.07)
Netliquidwealth	0.520***	0.581***	0.585***	1.418***	3.124***	3.450***	3.484***	5.618***
	(0.07)	(0.09)	(0.09)	(0.16)	(0.31)	(0.38)	(0.38)	(0.50)
Netliquidwealthsquared	-0.108***	-0.122***	-0.122***	-0.880***	-0.586***	-0.640***	-0.648***	-3.376***
	(0.02)	(0.03)	(0.03)	(0.14)	(0.07)	(0.08)	(0.08)	(0.42)
Personaldebt	1.191***	1.188***	1.183***	1.823***	3.696***	3.966***	3.953***	5.710***
	(0.33)	(0.33)	(0.33)	(0.52)	(0.90)	(0.94)	(0.94)	(1.43)
Housing	0.121***	0.052	0.061	0.139***	0.322***	0.211**	0.225**	0.273**
	(0.04)	(0.04)	(0.04)	(0.05)	(0.08)	(0.10)	(0.10)	(0.11)
Housingsquared	-0.021***	-0.011	-0.012	-0.039***	-0.049***	-0.027	-0.029	-0.051
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)
Outstandingmortgage	0.109***	0.130***	0.135***	0.183***	0.135	0.141	0.153	0.361**
	(0.04)	(0.04)	(0.04)	(0.06)	(0.10)	(0.10)	(0.10)	(0.15)
Grosslabourincome	-0.041		-0.046	-0.029	0.149		0.094	0.321
	(0.13)		(0.14)	(0.17)	(0.35)		(0.37)	(0.43)
Incomenlw	1.09E-04***		1.03E-04***	-3.97E-04	1.31E-04		1.25E-04	-0.001
	(4.02E-05)		(3.98E-05)	(5.88E-04)	(9.19E-05)		(9.20E-05)	-1.23E-03
Permanentincome		0.578				1.589*		
		(0.39)				(0.92)		

Permanentincomenlw		8.10E-05***				4.90E-05		
		(2.88E-05)				(5.98E-05)		
Age	0.036***	0.034***	0.045***	0.027***	0.051***	0.067**	0.091***	0.036**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.03)	(0.01)
Agesquared	-3.30E-04***	-2.93E-04*	-4.29E-04***	-2.39E-04***	-.4.79E-04***	-0.001*	-9.58E-04***	-3.28E-04**
	(7.05E-05)	(1.61E-04)	(1.40E-04)	(7.09E-05)	(1.52E-04)	(3.61E-04)	(3.17E-04)	(1.56E-04)
Aleveldum	0.045	1.26E-04	0.033	0.028	0.106	0.002	0.085	0.086
	(0.03)	(0.04)	(0.04)	(0.03)	(0.08)	(0.09)	(0.08)	(0.08)
Degreedum	0.076*	0.015	0.078*	0.034	0.213**	0.047	0.210*	0.155
	(0.04)	(0.06)	(0.05)	(0.05)	(0.11)	(0.14)	(0.11)	(0.11)
Pensiondum	0.034	0.021	0.020	0.021	0.029	-0.009	-0.013	-2.51E-04
	(0.04)	(0.04)	(0.04)	(0.04)	(0.09)	(0.09)	(0.09)	(0.09)
Employeedum	-0.090	-0.104	-0.099	-0.064	-0.206	-0.286	-0.311	-0.174
	(0.06)	(0.07)	(0.08)	(0.06)	(0.14)	(0.19)	(0.19)	(0.15)
Selfemployeddum	-0.164**	-0.166**	-0.159**	-0.141**	-0.253	-0.374*	-0.351	-0.186
	(0.07)	(0.08)	(0.08)	(0.07)	(0.17)	(0.21)	(0.22)	(0.18)
Unemployeddum	-0.194**	-0.237**	-0.236**	-0.165**	-0.406**	-0.534**	-0.554**	-0.357*
	(0.08)	(0.10)	(0.10)	(0.08)	(0.18)	(0.22)	(0.22)	(0.18)
Sexdum	0.033	0.048	0.059*	0.024	-0.023	-0.010	0.005	-0.068
	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)	(0.07)	(0.08)	(0.07)
Maritaldum	-0.008	0.008	0.003	-0.009	0.015	0.021	0.011	0.037
	(0.03)	(0.04)	(0.04)	(0.03)	(0.08)	(0.09)	(0.09)	(0.08)
Childdum	0.144**	0.129**	0.133**	0.112	0.222	0.202	0.214	0.083
	(0.06)	(0.06)	(0.06)	(0.07)	(0.14)	(0.14)	(0.14)	(0.15)
numberofkids	-0.042	-0.046	-0.046	-0.028	-0.098	-0.116*	-0.118*	-0.032
	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)	(0.07)	(0.07)	(0.08)
Londondum	-0.018	0.012	0.009	-0.008	0.018	0.057	0.042	0.049
	(0.05)	(0.05)	(0.05)	(0.05)	(0.11)	(0.12)	(0.12)	(0.12)

youngunhealthdum	0.007			0.010	0.068			0.110
	(0.14)			(0.14)	(0.30)			(0.30)
oldhealthdum	0.052			0.013	-0.098			-0.169
	(0.07)			(0.07)	(0.17)			(0.18)
oldunhealthdum	-0.348			-0.413*	-1.147**			-1.277**
	(0.23)			(0.23)	(0.52)			(0.54)
Healthstatus	-0.002	-0.002	-0.002	0.003	-0.046	-0.051	-0.052	-0.043
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)
Constant	-1.103***	-1.064***	-1.213***	-0.936***	-1.902***	-2.143***	-2.429***	-1.646***
	(0.16)	(0.24)	(0.23)	(0.16)	(0.34)	(0.52)	(0.49)	(0.36)
Log likelihood	-1746.030	-1348.959	-1349.649	-1594.447	-1103.464	-863.860	-864.515	-1017.110
LR chi2	515.53	385.16	383.78	505.09	809.06	607.91	607	788.14
Pro>chi2	0	0	0	0	0	0	0	0
Pseudo R2	0.1286	0.1249	0.1245	0.1367	0.2683	0.2603	0.2597	0.2792
No. of observations	2203	1708	1708	2057	2203	1708	1708	2057
Left-censored observations at α2000<=0	957	737	737	906				
Uncensored observations	1072	846	846	999				
Right-censored observations at α2000>=1	174	125	125	152				

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage,Grosslabourincome, and Permanentincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

3.4 Interpretation and Conclusion

We now turn to interpreting these results and drawing some conclusions. We consider firstly our Tobit estimation and then move on to the censored quantile regression.

In the Tobit model we identify a number of variables that have an influence on households' risky asset selection. Specifically, we find that individuals hold a higher share of risky assets when they have higher net liquid wealth. However, this effect is non-linear in the sense that for very high wealth households the effect reverses. Similar effect has been found in Alan *et al.'* (2010) work. They regressed the portfolio share of tax-favoured assets on four wealth dummies and reported that the coefficients for these four wealth dummies were 0.522, 0.645, 0.689 and 0.634 respectively. Other reserachers, for example, Hochguertel *et al.* (1997), and Wachter and Yogo (2010) who regressed on log net-worth found positive impact of wealth. In the context of theory, the positive impact of net liquid wealth on risky asset share is consistent with decreasing risk aversion as individual's become wealthier.

This link between wealth and asset choice is also observed with housing wealth. The inverse-U shape impact of housing wealth on risky asset shares can be explained by the overall effect from three sub-effects, namely, the negative house price risk, the negative housing consumption-commitment effect and the positive housing wealth effect, which we have detailed in the literature survey (chapter 2.7.1). That means if the property is worth less than the threshold, the positive housing wealth effect dominants. The house value will provide financial security and encourage the households to invest in risky assets. In other words, the individual will be less risk averse and be willing to invest in risky assets (ie: take large-payoff gambles) if he/she has large wealth in housing and is facing a big negative wealth shock (Chetty and Szeidl, 2007). In contrast, if the property is worth larger than the threshold, the negative house price risk and the negative housing consumption-commitment effect dominant. The negative house price risk effect has been explored by setting up a mean-variance portfolio model (Brueckner, 1997, Flavin and Yamashita, 2002) and by setting up a lifecycle portfolio model (Cocco, 2005). The negative housing consumption-commitment effect could come from the minimum house size requirement which forces the individual to invest in house and this housing investment keeps individual's liquid assets at a relatively low level, so he/she will choose not to participate in the stock market (Cocco, 2005, p555).

The positive impact of the ratio of the labour income to net liquid wealth implies that as households have more income relative to their wealth they are in a better position to meet habit level consumption or respond to really bad economic shocks. Hence they can hold a more risky portfolio. Although we have not found any other empirical work which regress on this variable of *incomenlw*, and we have not found effect of gross labour income in our regressions such as in Table 3.12, some researchers found positive effect of labour income, for example, Cocco (2005) and Alan *et al.* (2010), and some researchers did not (King and Leape 1998).

In addition, this study confirms the response of asset choice to age. Specifically, as individuals age they increase their share of risky asset, although above a certain age, relating to the time of retirement, the risky asset share declines. In the following chapter 4 we investigate further the impact of retirement on individual asset choice. The positive relationship between age and risk-asset share could be explained by risk aversion or through habit. In other words as individuals age their habit level of consumption does not grow as quickly as their income and hence risk aversion declines. This positive effect of age is consistent with the predication of portfolio theory with habit formation, which predicts that habit formation would provide strong motive for the young to save in risk-free assets in order to maintain their consumption level above habit for a longer horizon and hence invest less in risky assets (Polkovnichenko, 2007; Lax, 2002; Gupta, 2009). Much empirical evidence are also consistent with our findings that risky asset allocations tend to be an inverse U shape or increasing with age, for example, the findings in Ameriks and Zeldes (2004), Wachter and Yogo (2010), and Guiso *et al.* (2002). Guiso *et al.* (2002, pp11) reported that in the UK, Germany and Italy, there is "a hump-shaped age profile of participation in risky assets". The households in those three countries have the highest probability of holding risky assets when they are in the age of 50s, whereas in the Holland, instead of the hump-shaped relationship, age is found to have positive impact on households' risky asset holdings.

The impact of retirement on asset choice is also identified through the positive effect of the individual having a pension beyond the standard basic state provision. Again this is likely to reduce the probability of the household going close to its habit level, therefore increasing the willingness to take risk.

Education to degree standard provides a positive effect to risky asset share. This is unlikely to emanate from risk attitude but is probably a reflection of the ability to process information and make rational choices. It does suggest that financial decisions are complicated and the more individuals are used to processing such decisions the more ability they have to identify the benefits of investing in risky assets. The positive impact of education on risky assets share has also been found in some empirical studies. (for example, King and Leape 1998; Hochguertel *et al.*,1997). Alan *et al.* (2010) only found positive effect of education to high-school, and no effect of college and post college education.

The positive influence of debt (personal debt and outstanding mortgage) also suggests that the financial sophistication of the household is a determinant of the extent to which they invest in risky assets. For example, Cocco (2005) also found positive impact of relative mortgage on portfolio share of stocks.

The positive impact of the presence of child/children on risky asset choice is interesting. It is unclear what drives this effect, although possibly the presence of children in a family provides a security for old age which makes households more willing to take risk. Note, however, that this effect disappears when we take into account possible heteroscedasticity. In addition, we do not find effect of number of children on portfolio share of risky assets[27]. In other empirical studies, for example, Alan *et al.* (2010) found positive impact of number of small children on portfolio share of tax-favoured assets.

Finally employment status is seen to be important in the context of a negative influence of unemployment and being self-employed. It seems likely that such an effect comes from the effect that these two employment states have on the probability of falling close to habit level of consumption with the consequent rise in risk aversion.

The results from the censored quantile regression reveal that, for many of the explanatory variable there appears to be no significant difference between the conditional mean and quantile estimates of the effects. However, we identify a number of interesting results from this analysis. Firstly, for those households at the lower end of

[27] This results can be found in Table 3.12.

the conditional distribution we find the coefficient which represents how quickly they adjust to the desired portfolio is lower. The explanation for this could be related to disproportionately large transaction costs when trading small volumes of asset. The asymmetric impact of net liquid wealth could also be a reflection of transaction costs in that households with low shares of risky assets respond much more to net liquid wealth, suggesting that this could be an indicator of trade volume. Alternatively those with larger holding of wealth are less likely to approach their habit level of consumption and hence can take more risk. Housing wealth has similar effects, although restricted to the lowest and highest quantiles. This would tend to suggest support for the habit-based explanation since it is difficult to see how transactions costs would be a function of housing wealth. Age is observed to have a differential impact on asset holdings. This is further support for the importance of habit since we might expect this to vary according to an individual's age and wealth. The impact of employment status also could be driven by habit or just a reflection of the underlying consumption-based model where the correlation between labour income and asset return is a key determinant of the benefit of holding risky stocks.

Overall we may observe that our empirical results provide further support for the consumption-based view of portfolio selection particularly augmented with habit formation in preferences. There are clearly some policy conclusions that can be drawn about the way in which portfolios are structured and the extent to which incentives to hold a diversified portfolio are constrained by various household characteristics. If we would like to promote wealth holding among the lower income groups of society then the results of this paper suggest that we need to provide more support to such households in terms of financial education and in ensuring that they have a minimum safety net which will protect them should stock returns be low or negative. Whilst we do not analyse it here the following chapter 5 considers the impact of the tax system and we have further results which may be of interest.

4. The Impact of Retirement and Housing on Household Risky Asset Choice

4.1 Introduction

The research on asset portfolio of the older population has become popular in recent years for a number of reasons. Firstly, similar to other EU countries, and more generally globally, the UK is experiencing an ageing population (ONS, 2009). Based on national population projections in 2008, “the proportion of people aged 65 and over is projected to increase from 16 per cent in 2008 to 23 per cent by 2033”, which suggested that the expected growth rate of the older population was more than 40 percent (ONS, 2009). This was largely due to the demographics of baby-boomers, who were born after the Second World War up to the mid-1960s (ONS, 2009).

Secondly, it has been well documented that the elderly in the UK hold large amount of financial wealth. Based on survey data from BHPS, in 2005, the median net financial wealth was £21,000 for respondents with age between 60 and 69, and £18,503 for respondents with age of 70 and above. Both figures were considerably higher than £11,000 which was the median net financial wealth for the whole sample size of 15,627. The overall net financial wealth held by these elderly respondents in the BHPS 2005 survey accounted for approximately 50 percent of the total net financial wealth of the whole sample. Other research also suggest that not only in the UK, but also in other developed nations, for example the US, Canada, and Italy, the elderly holds substantial net financial wealth (OECD, 2008).

These financial assets are regarded as playing an important role in providing financial security for the elderly. The elderly may use the financial assets to finance their daily consumption when they are retired. In order to smooth their consumption overtime, they also may need to use the assets to hedge the financial risk, for example, financial risk from "illness or death of a spouse" (Coile and Milligan, 2009, pp227). Largely due to the improvements in health and welfare, life expectancies have increased in the recent decades. Hence nowadays households would be faced with managing larger portfolios over a longer expected investment horizon.

Clearly, "the shifts in both public and private pension schemes from defined benefit to defined contribution plans, such as those seen for employer-provided pensions in the US and in the public pension systems of Sweden and the United Kingdom" (Coiled and Milligan, 2009, pp247) would also reinforce the argument that households have to take more responsibility than before to save and manage their portfolios in order to secure and maintain their standard of living during the retirement period. Under the defined benefit pension plans, the elderly receive their pensions based on their historical salaries and employment durations, which is similar to receiving income from investment in risk-free assets in a retirement savings account (see e.g.: Campbell *et al*., 2001, pp440). Whereas under the defined contribution pension plans, although the amount of contribution the household needs to pay is defined, the benefit they will receive when they are retired is undefined. The households annuities are exposed to investment risk.

Moreover, household portfolio may also have an impact on stock prices, especially the portfolio for baby-boomers who are currently approaching retirement or are retired, because the UK has a large population of old individuals and they may release their equities to finance their consumptions, which would have "important implications for asset markets" (Kedar-Levy, 2006; Coile and Milligan, 2009, pp227).

As we can see, the asset portfolio starts to play a crucial role in financial security for the older population and it has also been considered as having some influence on asset markets. Due to all those factors, there is a growing research agenda which has explored older households' asset allocation, for example the portfolio holdings of the older population in the US (Hurd, 2001), the impact of health on the elderly' asset allocation (Yogo, 2009; Rosen and Wu, 2004; Feinstein and Ho, 2001; Wu, 2003; Poterba *et al.*,2009), as well as the effect of marital history and family status (Ulker, 2009; Poterba *et al.*,2009). However, not much attention has been paid to the group of individuals who are approaching their retirement age or have just retired and not much attention has been paid to investigate whether the event of retirement itself would have an impact on individuals' saving and investment behaviour. To carry out research on this specific group should be of particular interest. The elderly in this group may make different portfolio allocation decisions compared with individuals who are still in the labour force (Lai, 2008). The downward shift of their income and wealth when they are retired is commonly considered as the most influential factor (Hurd, 2001). In addition, compared with their labour income prior their retirement, their income streams from regular pensions and annuity are normally less correlated with the economic condition, which may encourage them to take relatively high risks in investment (Hurd, 2000). Although the impact of retirement on household asset allocation has not been studied yet, early retirement has been predicted to have a positive effect on risky asset allocations. Farhi and Panageas (2007) developed a theoretical model which suggests that if the agent is given an option to retire early then this option would motivate her to save and her optimal portfolio would be "tilted more towards stocks" (Farhi and Panageas, 2007, pp89). The reason is that in order to retire early and enjoy more leisure time, the individuals are more likely to save more at present and accumulate more wealth for their later consumptions during retirement. Investing a higher proportion of savings in risky assets is expected to earn higher returns and this would also "bring the retirement closer" (Farhi and Panageas, 2007, pp89). If, for example, in the future the actual return generated from the stock market does not meet expectation, individuals can postpone their retirement so that they can accumulate enough wealth for later consumption.

This theoretical prediction of early retirement effect from Farhi and Panageas's model is empirically tested in our research. This chapter try to contribute the current literature in the following ways. It investigates how the portfolios of the UK individuals evolve due to changes in retirement status by using data from the British Household Panel Survey (BHPS). In particular, it examines the impact of retirement and house ownership on the share of a household's total assets held in risky assets.

The remaining part of this paper is organized as follows. Section 4.2 explores the existing literature which examines older household asset allocation and the impact of retirement on the risky portfolio that households held. Section 4.3 provides further explanation why the BHPS dataset is still considered to be the reasonable survey data used to carry out the analysis in this chapter, followed by a discussion of the research methodology and results in Section 4.4 and Section 4.5 respectively. The conclusion is drawn at the end of the chapter.

4.2 Literature Review

As mentioned before, "baby-boomers", who were born after the Second World War up to the mid-1960s, are approaching their retirement (ONS, 2009). Since these elderly hold a large proportion of the UK's personal wealth, for example reported as 80% in 2004 (Walker, 2004), and these asset portfolios play a crucial part in financial security for the elderly and are considered as having some influence on asset markets, there is a growing interest in the research area on the asset allocation of the older generation (Coile and Milligan, 2009, p228). The common perception is that the young generation should invest primarily in equities. As they age, their investment portfolios need to be shifted towards a more balanced allocation and when they are old, they should invest primarily in bonds (Bali *et al.,* 2009, p817). This strategy is consistent with the expectation made in overlapping generation models as in Constantinides *et al*. (2002) and Constantinides and Duffie (1996). Constantinides *et al*. (2002) suggested that in an overlapping generation model with 60 generations, the youngest individuals would not invest for several years due to the borrowing constraints, and as they aged, they would invest in stocks and bonds. But the proportion of stocks would decrease as the investment horizon shrinked and the attractiveness of stocks diminished because of high volatility of stock return. From a theoretical perspective, the model suggested that the old generation would release their stock holdings to finance their consumption first. Compared with stocks, bonds were less risky, so bonds would be sold by the older households later (Kedar-Levy, 2006, p285). Similar results have been derived in Storesletten *et al.* paper (2001), which also used the OLG model but incorporateed individual labour risk and transactions were allowed among different cohorts (Kedar-Levy, 2006, p285). Hence, the OLG models predicted that age had a negative impact on risky asset allocations.

However, the theoretical model introduced by Farhi and Panageas (2007) predicts that as individuals age, they would invest a higher proportion of wealth in risky assets if they were facing a constant investment opportunity set and having constant labour income. This predication is consistent with much empirical evidence that risky asset allocations tend to be an inverse-U shape or increasing with age, for example, the findings in Ameriks and Zeldes (2001). The reason why Farhi and Panageas (2007) can have this interesting predication is that in their model, an agent was free to choose his/her consumption level, the amount of investments in risky asset and money market and importantly, the retirement time was also free to choose but he/she can only work full time or choose to retire. When he/she chose to work, his/her labour income was fixed. If he/she chose to retire, he/she could no longer enter the labour market again[28]. The investment opportunity set was constant in their model and there were no borrowing constraints and short selling was permitted. Under these assumptions, in order to retire early with sufficient wealth the agent was found to increase his/her savings overtime and his /her optimal portfolio would be tilted more towards risky asset. In other words, Farhi and Panageas's model (2007) may suggest that early retirement has a positive impact on risky asset allocations.

[28] Even if the agent is allowed to reenter the labour market with a lower income, the major predications are still valid (Farhi and Panageas, 2007).

There is significant evidence of the non-linear relationship between age and risky asset holdings. By using cross-sectional data, Guiso *et al.* (2002, pp11) reported that in the UK, Germany and Italy, there was "a hump-shaped age profile of participation in risky assets". The households in those three countries had the highest probability of holding risky assets when they were in the age of 50s, whereas in the Holland, instead of the hump-shaped relationship, age was found to have positive impact on households' risky asset holdings.

This non-linear relationship between age and risky asset holdings is consistent with the findings in Guiso and Jappelli's (2000) work. Guiso and Jappelli (2000) found that the proportion of wealth invested in risky assets decreased with age for the elderly who were retired (cited in Guiso and Paiella, 2008, p1139). This asset allocation behaviour of the elderly can be explained by the factors that were introduced in Hurd's (2001) work. He explored the portfolio holdings of the older population in the US by using the panel survey data of Assets and Health Dynamics among the Oldest Old (AHEAD). He identified several factors that may influence the elderly in determining different portfolio allocation decisions compared with those made by the households who were still in the labour force. Firstly, the downward shift of their income and wealth when they were retired was commonly considered as the most influential factor. Bardasi *et al*. (2002) reported that, by using the British Household Panel Survey data from 1991 to 1999, retirement was significantly correlated with decrease in UK households' economic wellbeing in terms of their income. This decline in income may have an impact on the elderly's risk attitudes towards investment in financial assets and hence may lead them to rebalance their asset portfolios when they had just entered their retirement status (Georgarakos, 2005). Secondly, the flexibility of labour supply from the older population may also have impact on their asset allocation decisions. In the Bodie-Merton-Samuelson (BMS) life-cycle model (1992), the labour supply was set to be endogenous, which implied that individuals were free to decide the amount of work they wanted to do in terms of daily working hours, number of jobs and retirement date, and they could adjust their labour supply continuously[29]. The logic in BMS model is that, compared with income from equity investment, the income stream from human capital is normally less risky, therefore, the greater flexibility of labour supply an individual has, the greater proportion of risky assets allocated in his/her portfolio. However, the elderly who are retired may have limited ability to go back to work and hence may not be able to hedge against the losses from risky asset investment. Thus, based on Bodie *et al*. (1992), the limitation of participation in the labour force for the elderly may have negative impact on their intention to invest in risky assets (Bodie and Crane, 1997, p15). This might suggest that a greater proportion of older households choose a zero risky asset allocation. Furthermore, the old population may have to save more in risk-free assets and invest less in risky assets in order to hedge against the risk associated with a high level of healthcare expenditure due to the effect of ageing (Hurd, 2001) , but whether this health concern effect would take place as soon as the individual enters the retirement was not investigated.

On the other hand, investment in risky assets for the elderly can also be affected by other factors which may have a positive impact on it. For example, Hurd

[29] The assumption of adjusting labour supply continuously without cost is not so realistic. "A more realistic model would allow limited flexibility in varying labour and leisure…. and analyze the retirement problem as an optimal stopping problem and to evaluate the accompanying portfolio effects." (Bodie *et al.*, 1992, p32). For example, the assumptions in Farhi and Panageas' (2007) paper are more realistic. The retirement time is free to choose but he/she can only work full time or choose to retire. When he/she chooses to work, his/her labour income is fixed. If he/she chooses to retire, he/she can no longer enter the labour market again.

(2001) pointed out that the retirees regularly received their pensions and annuity incomes, and these income streams may have different risks relative to the risks of labour income. The income stream from pensions and annuity were less correlated with the economic situation. When the economy was in recession, the probability of losing a job was increasing for working people while the probability of not receiving pensions was null for retirees. Therefore, to some extent the income stream from pensions and annuity were relatively safe and this would encourage the retirees and people who were approaching retirement to invest in risky assets so that they could benefit from taking sufficient risk in their investment portfolio. In addition, as mentioned above, the intention to accumulate enough wealth for later consumption in retirement could also have a positive impact on the elderly's risky asset allocations.

Although some attention has been made to study the asset allocation behaviour of the old population worldwide, there is no such literature that focuses on the impact of retirement on risky asset allocation for the elderly, in other words, whether or not the retirement itself has effect on the elderly' portfolio allocation. Therefore, this chapter use BHPS survey data to look closely at the investment decisions of a selected group consisting of British households who are approaching their retirement age or have just retired. There are three specific hypotheses that we test. The first hypothesis is that early retirement has a positive impact on risky asset shares. The second hypothesis is that normal retirement also has a positive impact on risky asset shares. The third hypothesis is that house ownership would have a positive impact on risky asset shares, in other words, the house ownership would provide extra financial security which encourages individuals to invest in risky assets.

4.3 Data

The research in this chapter uses the data from the British Household Panel Survey, specifically the Survey data collected in 1995 and 2000. The reason why we use the BHPS in this chapter is that it not only provides detailed financial wealth and asset information on a large number of British households but also information on labour market status as well as housing wealth (Banks et al., 2002b).

Most variables we are going to use in this chapter are similar to those in the previous chapter, so for a clear definition please refer to chapter 3.3.2. Just for a reminder, we define an individual as being in retirement if he/she reported him/herself as being retired in the corresponding BHPS survey. This definition of retirement has also been used in other research papers investigating patterns of labour market and analysing retirement behaviour (Bardasi *et al.,* 2002, p135). In the survey, the respondents are required to assess their labour market status by choosing from a list of options, including self-employed, employed, unemployed, retired, maternity leave, family care, full-time student, disabled, government training scheme and others. In our later analysis, we classify the household as a retiree only if he/she reported himself/herself as being retired. Similarly, working household refers to self-reported as being employed.

We also define the concept of early retirement. If an individual is female and is retired before age of 60 then she is classified as early retiree. Similarly, if an individual is male and is retired before age of 65 then he is classified as early retiree. We will use this definition to define an early retirement dummy variable in our later research in this chapter.

In addition, in the cross-section studies, the reason why I did not include the lagged dependent variable (*allocation 1995*) in the regression for the year 2000 is because I want to make my main specification the same for both cross-section studies. In the regression for the year 1995, there is no previous risky asset share data available (*allocation 1990)*. The BHPS survey started from 1991. Similar reasons for not using the previous period's risky asset share in the DD estimation and in the short panel study.

4.4 Research Methodology

4.4.1: Cross sectional studies for 1995 and 2000 respectively

In this chapter, we will first use individual level data from the British Household Panel Survey (BHPS) for 1995 and 2000 respectively. Our sample data are constructed from both the household files as well as the individual files of the BHPS. We will divide the sample into two subsamples, namely house-owner subsample and non-house owner subsample. For each subsample, we set up all the control variable as well as two retirement dummy variables, called early retirement dummy variable and normal retirement dummy variable, in order to examine the impact of retirement in 1995 and 2000 respectively on portfolio shares in risky assets. For comparison reasons, the whole sample in 1995 and 2000 are also used and examined. As we did in the previous chapter, diagnostic tests are calculated. By conducting a Lagrange multiplier test (LM test) of normality based generalized residuals (Chesher and Irish, 1987), we find the hypothesis of normally distributed error is rejected at a conventional significance levels. By conducting a conditional moment test (Pagan and Vella, 1989), we also reject the null hypothesis of homoskedsticity. Hence, we first set up a standard Tobit model, followed by hetroskedastic Tobit model.

4.4.2: Control and treatment groups (Difference-in-Difference (DD) estimation)

4.4.2.1: Definition of control and treatment groups under DD methods

We continue to use individual level data from the British Household Panel Survey (BHPS) for 1995 and 2000. Rather than carrying out cross-sectional studies, now we pool the data together and examine the impact of retirement during 1995 and 2000 on portfolio shares in risky assets by using the Difference-in-Difference method.

The simple case of DD method is defined by two groups, namely the treatment group and the control group, and two time periods. The treatment group is exposed to a treatment in the second period only and the control group is not exposed to the treatment in either period (Wooldridge, 2007). The DD method involves subtracting the average gain in the control group from the average gain in the treatment group across both periods. This method "removes biases in second period comparisons between the treatment and control group that could be the result from permanent differences between those groups, as well as biases from comparisons over time in the treatment group that could be the result of trends" (Wooldridge, 2007). A more detailed explanation of the DD approach can be found in later section 4.4.2.3.

Before we run the DD estimation, we need to define our treatment and control groups using the BHPS dataset. If he /she was employed in 1995 and was reported as being retired in 2000, then he/she would be regarded as a member of our treatment group. If the individual household was employed in 1995 and 2000, then he/she is classified as in the control group. Because we drop the observations when there is a missing value for our independent variable or any control variable, as we can see from Table 4.1, our treatment group consists of 86 respondents and control group consists of 907 respondents, which give us 993 respondents in total[30]. Since we expect a homeowner's demographic and economic variables would be quite different from a non-homeowner's, we divide the whole sample into two subsamples, one for house owners and the other for non-house owners. The former subsample consists of 73 respondents in the treatment group and 812 respondents in the control group. The latter subsample consists of 13 respondents in the treatment group and 95 respondents in the control group. Here we define a respondent as a house owner if he/she was living in a family that own the accommodation, no matter if the accommodation was owned outright or was still on mortgage. The outright owners could own the property through different means, including by a lump-sum payment, paying off their mortgage loans, and inheritance. A non-house owner is defined as a respondent who was living in a family that does not own the property and he/she may pay the rent to live.

Table 4. 1: Number of Observations for Treatment Group and Control Group in Different Sample

No. of observation	Treatment group	Control group
Total sample	86	907
House owner subsample	73	812
Non-house owner subsample	13	95

[30] In our earlier research, we have fewer control variables; hence the sample size is bigger. If we control for age, gender, gross income, gross housing value, net liquid wealth and personal debt only, then our treatment group consists of 106 respondents and control group consists of 1447 respondents, which give us 1553 respondents in total. We will present the results of the regression adjusted DD regression for this larger sample size in later section 4.5.3 Table 4.21.

4.4.2.2: Descriptive statistics for each group

The original summary data for the whole sample, the house owner sub-sample and non-house owner subsample are presented in Table (A), Table (B) and Table (C) respectively in the appendix. The following Table 4.2 is derived from Table (A), Table (B) and Table (C), which provides a better way of summarizing the data. If we look at the variable *allocation* first, which measures the individual's risky asset allocation, Table 4.2 suggests that in the whole sample the average risky asset allocation for the treatment group is higher than the average risky asset allocation for the control group in 1995 and 2000. In addition, from 1995 to 2000, the treatment group in the whole sample had an increase in average risky asset allocation, so did the control group in the whole sample. Notably, we have similar findings in the house owner sub-sample, but not in the non-house owner subsample. In the non-house owner subsample, although in 2000 individual's average risky asset allocation for treatment group is higher than the average risky asset allocation for control group, it is not the case in 1995. In 1995, the average risky asset allocation for the treatment group in the non-house owner sample is 19 percent, whereas for the control group in the non-house owner sample is 22 percent. The former increase to 41 percent in 2000, but the latter decrease slightly to 20 percent in 2000. In sum, as we can see, although there are increases of investment in risky assets for both groups in the house owner subsample, the proportion of increase for the treatment group members is less than that for the control group members. In contrast, in the non-house owner subsample, the average risky asset allocation actually increases significantly for the treatment group but it falls for the control group in 2000. Surely there are many factors that would have an impact on generating those differences, this chapter try to examine whether retirement itself could play a role in explaining the differences.

The value of net liquid wealth, as we can see from Table 4.2, increases from 1995 to 2000 for all control groups. In other words, the control group for the total sample has an average net liquid wealth of £7,940 in 1995 and it increases to £10,180 in 2000; the average net liquid wealth for the control group in the house owner sub-sample increases from £8,450 in 1995 to £10,180 in 2000; in the non-house owner subsample, the net liquid wealth for the control group has an average value of £3,570 in 1995 which rise to £4,880 in 2000. In comparison, in the non-house owner sub-sample as well as in the whole sample, the individuals who are in the treatment group are found to have less net liquid wealth in 2000 than in 1995. In addition, the individuals in the treatment group of the house owner sub-sample are having roughly the same average amount of net liquid wealth in both years. Another finding is that, on average, the house owners have much higher net liquid wealth than the non-house owners have regardless of labour force participation status and year.

Table 4.2 also suggests that the average amount of personal debt for house owners is generally higher than that for non-house owners. In both subsamples, the average personal debt for the treatment group decreases from 1995 to 2000, whereas the personal debt for the control group increases. It seems that approaching retirement or being retired would encourage individuals to reduce their personal debts, whereas staying in the labour force would encourage individuals to continue accumulating debts.

From 1995 to 2000, the average gross housing value for the house owners in the treatment group increases by 65 percent from £80,830 to £133,110, and meanwhile, the average gross house value for the house owners in the control group increases by 67 percent from £72,390 to £120,870.

An outstanding mortgage loan, which is defined as total outstanding mortgage loan of current living property and other properties, may not be zero for an individual who is a non-house owner because a non-house owner is defined as an individual who is living in a family that does not own the property they reside in and he/she may pay the rent to live. Therefore, there is a possibility that a non-house owner actually is paying mortgage on another property or properties. This could help us to explain why, in Table 4.2, the average outstanding mortgage loan for the treatment group in the non-house owner subsample is zero in 1995 and it increases to £2,460 in 2000. For the treatment group in the house owner subsample, the average outstanding mortgage loan drops significantly from £8,100 to £3,740. Compared with the treatment group in the house owner subsample, the control group in the house owner subsample has much higher average outstanding mortgage loan of £34,900 in 1995 and £38,620 in 2000.

The average gross labour income for the treatment group in the house owner subsample is £15,730 in 1995 and it falls to £260 in 2000 due to retirement. The reason why the average annual labour income of these respondents is still positive in 2000 could be that the retirement of some respondents take place sometime during the 2000. In contrast, in the same house owner subsample, the control group has an average gross labour income of £16,790 in 1995 and this increases to £20,780 in 2000. For the non-house owner subsample, similar patterns have been found. The treatment group receive no labour income after retirement and the control group receive an increased average labour income in 2000. The difference between these two subsamples is that, on average, house owners earn higher labour income than non house owners in each year.

Incomenlw, which measures the gross labour income to net liquid wealth ratio, has an average value of 85.79 for the treatment group in the house owner subsample in 1995 and falls to -0.02 after retirement in 2000. The control group in the same subsample has 29.67 in 1995 and it increased to 43.73 in 2000. For the non-house owner subsample, the treatment group drops its average *Incomenlw* from 68.79 to zero, whereas the control group increases the ratio from 38.37 to 210.45. However, as we can see from Table 4.2, the standard errors of the average values for this ratio are quite high, so we have to interpret these average values with caution.

Table 4.2 also suggests that no matter in the house owner subsample or in the non-house owner subsample, respondents in the treatment group are older than respondents in the control group. The average age for the treatment group in the whole sample is 58 in 1995 and it increases to 63 in 2000. The average age for the control group in the whole sample is 38 in 1995 and it increases to 43 in 2000.

In terms of education, we find that if a respondent was in the treatment group, then he/she would report the same highest education level in 2000 as it in 1995, no matter he/she is house owner or not. However, for the control group, we have a different situation. For the control group in the whole subsample, the dummy variable *olevelorunderdum* has an average value of 0.51 in 1995 and it reduces to 0.48 in 2000. This implies that for the control group in the whole sample there is 51 percent of respondents having O-levels or under as their highest level of qualification in 1995. This proportion drops to 48 percent in 2000. Meanwhile, for the same group, from 1995 to 2000, the proportion of respondents having an A-level or equivalent as their highest level of qualification increases from 33 percent to 34 percent, and the proportion of respondents having a degree level or higher as their highest level of qualification increases from 16 percent to 18 percent. In addition, for the control group in the house owner subsample and in the non-house owner subsample, we have similar findings for these education variables.

Pensiondum, a dummy variable which equals one if the respondent is involved in public or/and private pension schemes, is also summarized in Table 4.2. As we can see, the average value of *pensiondum* for the treatment group in the house owner subsample is 0.64 in 1995 and it falls to zero in 2000 after retirement. In other words, 64 percent of respondents in this group is involved in pension schemes in 1995 when they are employed and zero percent of respondents is involved in pension schemes in 2000 because no contribution is needed after retirement. In contrast, in the same house owner subsample, the control group has an average of 75 percent in pension participation in 1995 and this increases to 79 percent in 2000. For the non-house owner subsample, similar patterns have been found. The treatment group does not involve in pension schemes after retirement and the control group has an increased average pension participation rate in 2000. Notably, the difference between these two subsamples is that, on average, the pension participation rate is higher for house owners than that for non house owners in each year.

The four dummy variables for different labour market status are clearly presented in Table 4.2. *Employeedum* equals 1 for all treatment groups in 1995 and for all control groups in 1995 and 2000, no matter the groups are in the whole sample or in the two subsamples. *Retireddum* equals 1 for all treatment groups in 2000, including groups in the whole sample and two subsamples. The summaries for the *selfemployeddum* and *unemployeddum* suggest that we only consider two labour market status here, and respondents with other labour market status, such as self employed or unemployed, are not included in our sample.

As we know, in the whole sample, we have two groups, namely, the treatment group and the control group. In the former group, 53 percent of the respondents are male, whereas in the latter group, 51 percent of the respondents are male. In the house owner subsample, 56 percent of the respondents in the treatment group are male and 52 percent in the control group are male. In comparison, in the non-house owner subsample, 38 percent of the respondents in the treatment group are male and 39 percent in the control group are male.

In terms of marital status, Table 4.2 suggests that no matter in which sample, there is a higher proportion of married respondents in the treatment group than that in the control group. In addition, for each group in the house owner subsample, there is a higher proportion of married respondents than that in the corresponding group in non-house owner subsample.

As we can see from Table 4.2, in the house owner subsample there is only 3 percent of respondents in the treatment group having one or more children with age under 12 in the family in 1995 and this proportion reduces to 1 percent in 2000, whereas in the control group in the same subsample the proportion is 31 percent in 1995 and the same proportion remains in 2000. Similarly, in the non-house owner subsample, the control group has a higher proportion of respondents with young child/children in the family than the treatment group in each year.

The summaries for the dummy variable, *Londondum*, suggests that in the whole sample there is 8 percent of respondents in the treatment group living in greater London in 1995 and this proportion falls to 6 percent in 2000. Still in the whole sample, the proportion of respondents living in greater London in control group also drops from 11 percent to 10 percent. For the house owner subsample, the proportion drops for both groups from 1995 to 2000, while for the non-house owner subsample, the proportion dropped for the control group and it remains at zero for the treatment group.

Table 4. 2:Descriptive Statistics

Sample	Variable	Treatment group Mean	Std. Dev.	Control group Mean	Std. Dev.
The whole sample	allocation1995	0.36	[0.37]	0.28	[0.37]
	allocation2000	0.41	[0.38]	0.31	[0.37]
House owner subsample	allocation1995	0.39	[0.37]	0.28	[0.37]
	allocation2000	0.41	[0.37]	0.32	[0.37]
Non house owner subsample	allocation1995	0.19	[0.31]	0.22	[0.37]
	allocation2000	0.41	[0.43]	0.20	[0.35]
The whole sample	netliquidwealth1995	36.21	[77.87]	7.94	[30.00]
	netliquidwealth2000	35.97	[69.25]	10.18	[29.59]
House owner subsample	netliquidwealth1995	41.17	[83.42]	8.45	[31.52]
	netliquidwealth2000	41.26	[73.95]	10.80	[30.91]
Non house owner subsample	netliquidwealth1995	8.34	[14.37]	3.57	[8.85]
	netliquidwealth2000	6.25	[5.58]	4.88	[12.64]
The whole sample	personaldebt1995	0.55	[1.12]	1.19	[2.44]
	personaldebt2000	0.08	[0.34]	2.03	[5.24]
House owner subsample	personaldebt1995	0.65	[1.19]	1.26	[2.52]
	personaldebt2000	0.09	[0.37]	2.11	[5.41]
Non house owner subsample	personaldebt1995	0.02	[0.06]	0.61	[1.42]
	personaldebt2000	0	[0]	1.39	[3.38]
The whole sample	housing1995	68.61	[49.01]	64.81	[45.45]
	housing2000	112.99	[98.53]	108.21	[91.70]
House owner subsample	housing1995	80.83	[42.83]	72.39	[41.94]
	housing2000	133.11	[93.51]	120.87	[88.67]
Non house owner subsample	housing1995	0	[0]	0	[0]
	housing2000	0	[0]	0	[0]

The whole sample	outstandingmortgage1995	6.88	[	14.98	]	31.30	[	31.67	]
	outstandingmortgage2000	3.55	[	11.51	]	34.69	[	38.77	]
House owner subsample	outstandingmortgage1995	8.10	[	15.97	]	34.90	[	31.51	]
	outstandingmortgage2000	3.74	[	11.96	]	38.62	[	39.06	]
Non house owner subsample	outstandingmortgage1995	0	[	0	]	0.57	[	5.54	]
	outstandingmortgage2000	2.46	[	8.88	]	1.09	[	7.12	]
The whole sample	grossincome1995	14.35	[	11.67	]	16.13	[	12.56	]
	grossincome2000	0.22	[	1.40	]	19.87	[	15.09	]
House owner subsample	grossincome1995	15.73	[	12.05	]	16.79	[	12.89	]
	grossincome2000	0.26	[	1.52	]	20.78	[	15.47	]
Non house owner subsample	grossincome1995	6.59	[	4.01	]	10.50	[	7.15	]
	grossincome2000	0.00	[	0.00	]	12.10	[	7.87	]
The whole sample	incomenlw1995	83.22	[	678.59	]	30.58	[	280.59	]
	incomenlw2000	-0.01	[	0.74	]	61.19	[	653.00	]
House owner subsample	incomenlw1995	85.79	[	730.89	]	29.67	[	277.52	]
	incomenlw2000	-0.02	[	0.81	]	43.73	[	435.74	]
Non house owner subsample	incomenlw1995	68.79	[	237.14	]	38.37	[	307.09	]
	incomenlw2000	0.00	[	0.00	]	210.45	[	1564.17	]
The whole sample	age1995	57.90	[	6.04	]	37.84	[	10.42	]
	age2000	63.06	[	6.02	]	43.02	[	10.41	]
House owner subsample	age1995	57.37	[	6.21	]	37.88	[	10.05	]
	age2000	62.52	[	6.18	]	43.05	[	10.04	]
Non house owner subsample	age1995	60.85	[	3.93	]	37.45	[	13.21	]
	age2000	66.08	[	3.93	]	42.73	[	13.17	]

The whole sample	olevelorunderdum1995	0.80	[	0.40	]	0.51	[	0.50	]
	olevelorunderdum2000	0.80	[	0.40	]	0.48	[	0.50	]
House owner subsample	olevelorunderdum1995	0.79	[	0.41	]	0.49	[	0.50	]
	olevelorunderdum2000	0.79	[	0.41	]	0.46	[	0.50	]
Non house owner subsample	olevelorunderdum1995	0.85	[	0.38	]	0.71	[	0.46	]
	olevelorunderdum2000	0.85	[	0.38	]	0.67	[	0.47	]
The whole sample	aleveldum1995	0.10	[	0.31	]	0.33	[	0.47	]
	aleveldum2000	0.10	[	0.31	]	0.34	[	0.47	]
House owner subsample	aleveldum1995	0.10	[	0.30	]	0.34	[	0.47	]
	aleveldum2000	0.10	[	0.30	]	0.35	[	0.48	]
Non house owner subsample	aleveldum1995	0.15	[	0.38	]	0.19	[	0.39	]
	aleveldum2000	0.15	[	0.38	]	0.21	[	0.41	]
The whole sample	degreedum1995	0.09	[	0.29	]	0.16	[	0.37	]
	degreedum2000	0.09	[	0.29	]	0.18	[	0.39	]
House owner subsample	degreedum1995	0.11	[	0.31	]	0.17	[	0.37	]
	degreedum2000	0.11	[	0.31	]	0.19	[	0.39	]
Non house owner subsample	degreedum1995	0	[	0	]	0.11	[	0.31	]
	degreedum2000	0	[	0	]	0.12	[	0.32	]
The whole sample	pensiondum1995	0.60	[	0.49	]	0.72	[	0.45	]
	pensiondum2000	0	[	0	]	0.77	[	0.42	]
House owner subsample	pensiondum1995	0.64	[	0.48	]	0.75	[	0.43	]
	pensiondum2000	0	[	0	]	0.79	[	0.41	]
Non house owner subsample	pensiondum1995	0.38	[	0.51	]	0.49	[	0.50	]
	pensiondum2000	0	[	0	]	0.61	[	0.49	]

The whole sample	employeedum1995	1	[	0	]	1	[	0	]
	employeedum2000	0	[	0	]	1	[	0	]
House owner subsample	employeedum1995	1	[	0	]	1	[	0	]
	employeedum2000	0	[	0	]	1	[	0	]
Non house owner subsample	employeedum1995	1	[	0	]	1	[	0	]
	employeedum2000	0	[	0	]	1	[	0	]

The whole sample	selfemployeddum1995	0	[	0	]	0	[	0	]
	selfemployeddum2000	0	[	0	]	0	[	0	]
House owner subsample	selfemployeddum1995	0	[	0	]	0	[	0	]
	selfemployeddum2000	0	[	0	]	0	[	0	]
Non house owner subsample	selfemployeddum1995	0	[	0	]	0	[	0	]
	selfemployeddum2000	0	[	0	]	0	[	0	]

The whole sample	retireddum1995	0	[	0	]	0	[	0	]
	retireddum2000	1	[	0	]	0	[	0	]
House owner subsample	retireddum1995	0	[	0	]	0	[	0	]
	retireddum2000	1	[	0	]	0	[	0	]
Non house owner subsample	retireddum1995	0	[	0	]	0	[	0	]
	retireddum2000	1	[	0	]	0	[	0	]

The whole sample	unemployeddum1995	0	[	0	]	0	[	0	]
	unemployeddum2000	0	[	0	]	0	[	0	]
House owner subsample	unemployeddum1995	0	[	0	]	0	[	0	]
	unemployeddum2000	0	[	0	]	0	[	0	]
Non house owner subsample	unemployeddum1995	0	[	0	]	0	[	0	]
	unemployeddum2000	0	[	0	]	0	[	0	]

The whole sample	sexdum1995	0.53	[	0.50	]	0.51	[	0.50	]
	sexdum2000	0.53	[	0.50	]	0.51	[	0.50	]
House owner subsample	sexdum1995	0.56	[	0.50	]	0.52	[	0.50	]
	sexdum2000	0.56	[	0.50	]	0.52	[	0.50	]
Non house owner subsample	sexdum1995	0.38	[	0.51	]	0.39	[	0.49	]
	sexdum2000	0.38	[	0.51	]	0.39	[	0.49	]
The whole sample	maritaldum1995	0.72	[	0.45	]	0.66	[	0.47	]
	maritaldum2000	0.71	[	0.46	]	0.68	[	0.46	]
House owner subsample	maritaldum1995	0.75	[	0.43	]	0.69	[	0.46	]
	maritaldum2000	0.74	[	0.44	]	0.72	[	0.45	]
Non house owner subsample	maritaldum1995	0.54	[	0.52	]	0.38	[	0.49	]
	maritaldum2000	0.54	[	0.52	]	0.35	[	0.48	]
The whole sample	childdum1995	0.02	[	0.15	]	0.30	[	0.46	]
	childdum2000	0.02	[	0.15	]	0.29	[	0.46	]
House owner subsample	childdum1995	0.03	[	0.16	]	0.31	[	0.46	]
	childdum2000	0.01	[	0.12	]	0.31	[	0.46	]
Non house owner subsample	childdum1995	0.00	[	0.00	]	0.21	[	0.41	]
	childdum2000	0.08	[	0.28	]	0.17	[	0.38	]
The whole sample	londondum1995	0.08	[	0.28	]	0.11	[	0.31	]
	londondum2000	0.06	[	0.24	]	0.10	[	0.31	]
House owner subsample	londondum1995	0.10	[	0.30	]	0.11	[	0.31	]
	londondum2000	0.07	[	0.25	]	0.10	[	0.30	]
Non house owner subsample	londondum1995	0	[	0	]	0.13	[	0.33	]
	londondum2000	0	[	0	]	0.12	[	0.32	]

Note: standard errors are in square brackets..

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

4.4.2.3: The fundamental concept behind the difference-in-difference (DD) estimation

The fundamental concept behind the difference-in-difference (DD) estimation can be explained by using Table 4.3. Suppose PA1 and PA2 represents the average portfolio share in risky assets for the control group in the whole sample in 1995 and 2000 respectively, and PA3 and PA4 denotes the average portfolio share in risky assets for treatment group in the whole in 1995 and 2000 respectively:

Table 4. 3:Simple illustration for DD methods

	Control group (*dumtreatment*=0)	Treatment group (*dumtreatment*=1)
1995 (*timedummy*=0)	PA1	PA3
2000 (*timedummy=1*)	PA2	PA4

The change in portfolio share for the treatment group over 1995 and 2000 is *PA4-PA3*. Some of this change may be attributed to the change in the labour force participation status and the other part is due to external factors, for example changes in interest rates. The assumption we made for the DD estimator is that individuals in the control group reflect those external factors in the change in their portfolio share, which is denoted as *PA2-PA1.* This "common trends" assumption is a fundamental concept of DD estimation. Therefore, an estimate of the impact of retirement on the portfolio allocation in the treatment group is *(PA4-PA3)- (PA2-PA1).* In other words, basically we need to compare the portfolio share change of individual who are in the transition period to retirement with that of individuals who are employed all the time, under the assumption that they would have reallocated their portfolio share in the same way and same amount in the absence of changes in labour force participation status.

However, the “common trends” assumption may not be satisfied, because the control group and treatment group may “differ in time trends of either observable or unobservable characteristics or both” Crossley and Jeon, 2007, p355). As we have already seen in section 4.4.2.2, many observable factors, such as net liquid wealth, personal debt, gross housing value, outstanding mortgage loans and gross labour income, had different average values for the control group and the treatment group in 1995 and 2000. These observable group characteristics or other unobservable group characteristics or both can explain the difference between the changes in portfolio shares which refers to *(PA4-PA3)- (PA2-PA1)*. A possible remedy is to carry out a regression-adjusted DD estimation. By controlling for the relevant and observable factors, this remedy would reduce the bias that is caused by the different changes over time in the observable characteristics between the control group and the treatment group (Meyer, 1995; Crossley and Jeon, 2007). Meyer (1995) also points out that compared with a simple DD estimation approach, this regression-adjusted DD estimation method would lead to more efficient estimates.

In addition, Wooldridge (2002, p130) also pointed out that in most situations, extra explanatory variables were needed in the simple DD model, because in the simple DD model, “unbiasedness of the DD estimator requires that the policy change not be systematically related to other factors that affect the dependent variable (and are hidden in the error term)”. In comparison, in the regression-adjusted DD model, adding extra explanatory variables “allows for the possibility that the random samples within a group have systematically different characteristics in the two time periods” (Wooldridge, 2002, p130).

Therefore, besides running the following simple DD regression,

$$\alpha_{it}^{*} = \beta_0 + \beta_1 \ dumtreatment_i + \beta_2 timedummy_t + \beta_3 (timedummy * dumtreatment)_{it} + \varepsilon_{it} \ ,$$

$$\varepsilon_{it} \sim N(0,\sigma^2)\,, \tag{1}$$

where $\alpha_{it} = \begin{bmatrix} 0 & if\alpha_{it}^{*} \le 0 \\ \alpha_{it}^{*} & if\,0 < \alpha_{it}^{*} \le 1 \\ 1 & if\alpha_{it}^{*} > 1 \end{bmatrix}$

we would also augment it with regression-adjusted DD estimation, which is specified as follows:

$$\alpha_{it}^{*} = \beta_0 + \beta_1 \ dumtreatment_i + \beta_2 timedummy_t + \beta_3 (timedummy * dumtreatment)_{it} + \beta_4 X_{it} +$$

$$\varepsilon_{it}\,,\ \varepsilon_{it} \sim N(0,\sigma^2)\,, \tag{2}$$

where

$$\alpha_{it} = \begin{bmatrix} 0 & if\alpha_{it}^{*} \le 0 \\ \alpha_{it}^{*} & if\,0 < \alpha_{it}^{*} \le 1 \\ 1 & if\alpha_{it}^{*} > 1 \end{bmatrix}.$$

Since our portfolio allocation data are left censored at zero if the respondent does not invest in the risky assets, and are right censored at one if the respondent invest all his/her wealth in the risky assets, we estimate via a Tobit regression which allows for data censoring both at zero and one. In this estimation, the portfolio share, α_{it}*, is the latent variable which indicates the proportion of personal wealth that would notionally be invested in the risky assets. We control for a series of socioeconomic and demographic variables, including net liquid wealth, personal debt, gross housing value, outstanding mortgage loan, gross labour income, gross labour income to net liquid wealth ratio, age, education, pension participation, gender, marital status, children and regional dummy variable. All these control variables are given by X_{it} in equation 2 and the detailed definition for each variable are the same as in the earlier chapter 3 and can be referred back to section 3.3.2 of Chapter 3. In later sections, we will run simple DD estimation and regression-adjusted DD estimation for the whole sample as well as the two subsamples, namely the house owner subsample and the non-house owner subsample. We expect that the estimation results would be different for these two subsamples since we have observed that respondents in these two subsamples clearly possessed different socioeconomic status. Hence, for the whole sample and for the house owner subsample, we would control for all the variables we mentioned above, but for the non-house owner subsample, we could omit the variable of gross housing value.

In chapter 3, we have identified that these factors have an impact on households' risky asset allocation and hence this explains our choice of control variables in equation 2. Note that *gross labour income* refers to the households' annual labour income only. Income from savings and investments are not included in order to avoid potential endogeneity problem of the portfolio share and income variables; *dumtreatment* is a dummy variable which equals to one if the respondent is in the treatment group, in other words, if the respondent was reported as being retired in 2000 but being employed in 1995. It captures "possible differences between the treatment and control groups prior to the policy change" (Wooldridge, 2007, p3), where policy change refers to the change in labour force participation status. The sign of coefficient β_1 in equation 2 is not easy to predict, because as can been seen in Table 4.2, the respondents in the treatment group tend to be older, owe relatively less debt and their average annual labour income drop dramatically in 2000. However, they have much higher average net liquid wealth than individuals in the control group over 1995 and 2000 respectively. This economic condition would make the households' investment decision much more unpredictable.

Reduced income is supposed to have a negative impact on investment in risky assets, whereas the effect of higher net financial wealth on the risky asset allocation could be positive. If households have high net financial wealth, then they may be more willing to take risk and hence invest a higher proportion of wealth in risky assets.

In equation 2, the dummy variable *timedummy* equals to one for 2000 and equals to zero for 1995. This dummy variable captures "aggregate factors that would cause changes in y even in the absence of a policy change" (Wooldridge, 2007, p3). Its coefficient, β_2, is expected to be negative if the respondents were able to foresee stock market crash. In order to examine the effect of retirement on households' risk portfolio allocation, we need to examine to what extent the treatment group change their portfolio shares relatively to the control group. The sign of β_3, which is the coefficient of variable *timedummydumtreatment*, would reveal whether retirement has a positive or negative impact on portfolio share in risky assets.

4.4.3 Short panel study on the joint impact of retirement and housing ownership

In this chapter, we will also carry out a short panel study on the joint impact of retirement and house ownership by using 1995 and 2000 BHPS data. We control all the relevant economical and demographical variables and set up three dummy variables, namely *Dumhosuingr, Dumhousingw, Dumnonhousingr. Dumnonhousingw* is omitted to avoid multicolinearlity in the estimation. The definitions for these four variables are as follows. *Dumhosuingr* equals one if in both years the individual is retired and is living in an accommodation that is owned by him/her or by his family. It equals zero if otherwise. *Dumhousingw* equals one if in both years the individual is employed and is living in an accommodation that is owned by him/her or by his family. It equals zero if otherwise. *Dumnonhousingr* equals one if in both years the individual is retired and is living in an accommodation that is not owned by him/her or by his family. It equals zero if otherwise. *Dumnonhousingw* equals one if in both years the individual is employed and is living in an accommodation that is not owned by him/her or by his family. It equals zero if otherwise.

4.5 Estimation Results

4.5.1 cross-sectional estimations for 1995 and 2000 respectively[31]

Table 4.4 and Table 4.5 present the standard homoscedastic Tobit estimation results for the whole sample and two subsamples using 1995 BHPS data and using 2000 BHPS data respectively. Table 4.6, 4.7 and 4.8 show the standard homoscedastic Tobit and heteroscedastic Tobit estimation results for the whole sample, house-owner subsample and non house-owner subsample respectively based on 1995 of BHPS data. Whereas Table 4.9, 4.10 and 4.11 describe the standard homoscedastic Tobit and heteroscedastic Tobit estimation results for the whole sample, house-owner subsample and non house-owner subsample respectively based on 2000 of BHPS data.

As we can see, all else equal, in 1995, for the whole sample, the first column in Table 4.4 and the first column in Table 4.6 show that if the individual opt for early retirement, then his/her average risky asset share will increase by 13.6 percentage point. Even the normal retirement will increase the average risky asset share by 3.3 percentage point, although these effects are not statistically significant. If we control for the heteroscedastic problem, as in Table 4.6, both the early retirement and normal retirement still have a positive impacts. The former increases the average risky asset share by 7.4 percentage point and the latter increases it by 2.3 percentage point, which is present in Table 4.6, although, again, these effects are not statistically significant.

[31] We also set up a probit model which regresses the early retirement dummy variable on risky asset shares while controling for social and demographical factors, but the results is in conclusive.

For the house-owner subsample in 1995, all else equal, the second column in Table 4.4 and the first column in Table 4.7 suggest that having retired early will increase an individual's average risky asset share by 21 percentage point, and this effect is significantly from zero at the 5% level. In comparison, normal retirement will only increase the average risky asset share by 4.8 percentage point and it is not statistically significant. After controlling for the heteroscedastic problem, the early retirement's effect is reduce to 10.1 percentage point and normal retirement effect is dropped to 0.0116 percentage point. Both effects are statistically insignificant.

For the non house-owner subsample in 1995, all else equal, the third column in Table 4.4 and the first column in Table 4.8 tell us that both early retirement and normal retirement would have no effect on risky asset shares for individuals without housing ownership. This results remains if we control for the heteroscedastic problem, as we can see from the results in Table 4.8.

We also notice that for the non house-owner subsample, a pension has a very significant positive impact on individual's risky asset allocations. The coefficient of *Pensiondum* is 0.211 in Table 4.4 which is significantly from zero at 10% level and it is 0.266 in Table 4.8 which, unfortunately, is not statistically significant. In comparison, this pension effect is not that huge for the house-owner subsample. In Table 4.4, we can see that the coefficient of *Pensiondum* is 0.075 and it equals 0.104 after controlling the heteroscedastic problem. Both coefficients are statistically significant.

This huge impact of pension on risky asset allocations has not only been found in 1995 using the BHPS data but also been found in 2000 of BHPS survey. Participating in private and/or public pension schemes will increase the individual's average risky asset share by 11.4 percentage point for the house-owners and increase by 25.4 percentage point for the non-house owners. The former effect is significantly from zero at the 1% level and the latter effect is significantly different from zero at the 5% level, which has been showed in the following Table 4.5. After controlling for the heteroscedastic problem, the pension effect is increased to 14.7 percentage point for the house-owners and is still significantly from zero at the 1% level, and for the non-house owners the effect is increased dramatically to 52.3 percentage point and it is also significantly from zero at the 1% level. Table 4.10 and Table 4.11 present these statistics respectively.

The effect of early retirement and normal retirement on the risky asset share in 2000 is positive and statistically significant for the whole sample in both standard homoscedastic Tobit and heteroscedastic Tobit estimations. The effect of early retirement on the risky asset share in 2000 is positive and statistically significant for the house owner sample in both standard homoscedastic Tobit and heteroscedastic Tobit estimations. Still for the house owner sample, the effect of normal retirement on the risky asset share in 2000 is null under homoscedastic Tobit but is significantly positive under heteroscedastic Tobit. For non-house owners, neither early retirement nor normal retirement has been found to have an effect on risky asset shares in 2000 in in both standard homoscedastic Tobit and heteroscedastic Tobit estimations. The detailed results for standard homoscedastic Tobit and heteroscedastic Tobit estimations for the whole sample, house-owner subsample and non house-owner subsample for 2000 can be found in the following Table 4.9, Table 4.10 and Table 4.11 respectively.

Table 4. 4: The standard Tobit estimations for the whole sample and two subsamples for 1995 BHPS data

	Coefficients		
Variables	Model 1 total sample	Model 2 house owner sample	Model 3 Non-house owner sample
Dum early retirement	0.136	0.210**	-0.524
	(0.09)	(0.09)	(0.39)
Dum normal retirement	0.033	0.048	-0.160
	(0.07)	(0.08)	(0.20)
Net liquid wealth	0.554***	0.494***	2.167***
	(0.06)	(0.06)	(0.40)
Net liquid wealth squared	-0.056***	-0.050***	-0.638***
	(0.01)	(0.01)	(0.16)
Personaldebt	1.476***	1.382**	3.403
	(0.56)	(0.56)	(2.20)
Housing	0.323***	0.296***	
	(0.05)	(0.07)	
Housing squared	-0.040***	-0.035**	
	(0.02)	(0.02)	
Outstanding mortgage loans	0.039	0.045	-0.694
	(0.06)	(0.06)	(0.60)
Gross labour income	0.073	0.234	-1.944**
	(0.18)	(0.18)	(0.90)
Incomenlw	8.56E-05***	1.40E-04***	4.63E-05
	(2.68E-05)	(3.76E-05)	(5.47E-05)
Age	0.026***	0.024***	0.027**
	(0.01)	(0.01)	(0.01)
Agesquared	-1.86E-04***	-1.66E-04**	-1.84E-04
	(5.84E-05)	(6.73E-05)	(1.39E-04)
aleveldum	0.072**	0.059*	0.119
	(0.03)	(0.04)	(0.13)
Degreedum	0.086*	0.055	0.204
	(0.05)	(0.05)	(0.15)
Pensiondum	0.084**	0.075*	0.211*
	(0.04)	(0.04)	(0.12)
Sexdum	0.068**	0.064**	0.091
	(0.03)	(0.03)	(0.09)
Maritaldum	0.060*	0.049	0.083
	(0.03)	(0.04)	(0.09)
Childdum	0.045	0.038	0.115
	(0.04)	(0.04)	(0.13)

Londondum	0.043	-0.014	0.274**
	(0.04)	(0.05)	(0.12)
Constant	-1.261***	-1.170***	-1.483***
	(0.12)	(0.14)	(0.33)
Log likelihood	-2631.68	-2051.19	-545.10
LR chi2	552.46	408.19	87.26
Pro>chi2	0	0	0
Pseudo R2	0.095	0.091	0.074
No. of observations	3387	2558	829
Left-censored observations at α2000<=0	1892	1294	598
Uncensored observations	1289	1105	184
Right-censored observations at α2000>=1	206	159	47

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 5: The standard Tobit estimations for the whole sample and two subsamples for 2000 BHPS data

	Coefficients		
	Model 1	Model 2	Model 3
Variables	total sample	house owner sample	Non-house owner sample
Dum early retirement	0.139**	0.126**	0.282
	(0.06)	(0.06)	(0.34)
Dum normal retirement	0.098*	0.078	0.300
	(0.06)	(0.06)	(0.22)
Net liquid wealth	1.016***	0.914***	2.303***
	(0.07)	(0.06)	(0.44)
Net liquid wealth squared	-0.222***	-0.200***	-0.514***
	(0.02)	(0.02)	(0.14)
Personaldebt	1.773***	1.614***	2.581
	(0.22)	(0.21)	(1.73)
Housing	0.209***	0.160***	
	(0.03)	(0.03)	
Housing squared	-0.034***	-0.026***	
	(0.01)	(0.01)	
Outstanding mortgage loans	0.073*	0.082**	0.550
	(0.04)	(0.04)	(0.48)
Gross labour income	0.033	0.054	0.268
	(0.13)	(0.12)	(0.91)
Incomenlw	-2.57E-05	-6.35E-05*	0.000
	(1.72E-05)	(3.76E-05)	(0.00)
Age	0.029***	0.027***	0.034**
	(4.40E-03)	(4.79E-03)	(0.01)
Agesquared	-2.43E-04***	-2.19E-04***	-0.000**
	(4.51E-05)	(4.96E-05)	(0.00)
aleveldum	0.067**	0.032	0.353***
	(0.03)	(0.03)	(0.13)
Degreedum	0.055	0.038	0.181
	(0.04)	(0.04)	(0.16)
Pensiondum	0.134***	0.114***	0.254**
	(0.03)	(0.03)	(0.13)
Sexdum	0.071***	0.061***	0.149
	(0.02)	(0.02)	(0.09)
Maritaldum	0.016	0.010	-0.009
	(0.03)	(0.03)	(0.10)
Childdum	0.053	0.051	0.115
	(0.03)	(0.03)	(0.14)
Londondum	0.036	-0.007	0.242
	(0.05)	(0.05)	(0.15)
Constant	-1.190***	-1.070***	-1.973***
	(0.10)	(0.11)	(0.36)
Log likelihood	-4073.1477	-3196.70	-795.26

LR chi2	801.6	583.28	80.84
Pro>chi2	0	0	0
Pseudo R2	0.090	0.084	0.048
No. of observations	4927	3807	1120
Left-censored observations at α2000<=0	2505	1695	810
Uncensored observations	2036	1815	221
Right-censored observations at α2000>=1	386	297	89

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 6:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the whole sample in 1995 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	γ
Dum early retirement	0.136	0.074	-0.136
	(0.09)	(0.07)	(0.25)
Dum normal retirement	0.033	0.023	-0.043
	(0.07)	(0.06)	(0.20)
Net liquid wealth	0.554***	0.726***	-1.240***
	(0.06)	(0.08)	(0.15)
Net liquid wealth squared	-0.056***	-0.184***	0.240***
	(0.01)	(0.03)	(0.03)
Personaldebt	1.476***	0.529	7.063***
	(0.56)	(1.04)	(2.51)
Housing	0.323***	0.292***	-0.035*
	(0.05)	(0.07)	(0.20)
Housing squared	-0.040***	-0.050***	0.107*
	(0.02)	(0.02)	(0.08)
Outstanding mortgage loans	0.039	0.201***	0.154
	(0.06)	(0.07)	(0.19)
Gross labour income	0.073	-1.38E-01	-1.369**
	(0.18)	(0.09)	(0.55)
Incomenlw	8.56E-05***	5.92E-04***	8.36E-04***
	(2.68E-05)	(1.65E-04)	(2.24E-04)
Age	0.026***	0.03898***	-0.008
	(0.01)	(0.01)	(0.01)
Agesquared	-1.86E-04***	-2.71E-04***	-6.03E-05
	(5.84E-05)	(5.64E-05)	(0.00)
Aleveldum	0.072**	0.138***	-0.278***
	(0.03)	(0.03)	(0.10)
Degreedum	0.086*	0.092**	0.068
	(0.05)	(0.04)	(0.13)
Pensiondum	0.084**	0.134***	-0.085
	(0.04)	(0.04)	(0.12)
Sexdum	0.068**	0.046	0.162*
	(0.03)	(0.03)	(0.09)
Maritaldum	0.060*	0.090**	-0.302***
	(0.03)	(0.03)	(0.10)
Childdum	0.045	-0.059	0.578***
	(0.04)	(0.05)	(0.13)
Londondum	0.043	0.033	-0.010
	(0.04)	(0.04)	(0.13)
constant	-1.261***	-1.702***	
	(0.12)	(0.16)	

Log likelihood	-2631.68	-2480
No. of observations	3387	3387
left-censored observations at α2000<=0	1892	1892
uncensored observations	1289	1289
right-censored observations at α2000>=1	206	206

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 7:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the house-owner subsample in 1995 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	γ
Dum early retirement	0.210**	0.101	-0.138
	(0.09)	(0.07)	(0.26)
Dum normal retirement	0.048	1.16E-04	-0.007
	(0.08)	(0.06)	(0.23)
Net liquid wealth	0.494***	0.642***	-1.273***
	(0.06)	(0.08)	(0.17)
Net liquid wealth squared	-0.050***	-0.161***	0.238***
	(0.01)	(0.03)	(0.03)
Personaldebt	1.382**	0.873	4.87*
	(0.56)	(1.00)	(2.55)
Housing	0.296***	0.235***	-0.214
	(0.07)	(0.07)	(0.23)
Housing squared	-0.035**	-0.026***	0.061
	(0.02)	(0.01)	(0.08)
Outstanding mortgage loans	0.045	0.110	0.371*
	(0.06)	(0.07)	(0.22)
Gross labour income	0.234	-0.068	-1.426**
	(0.18)	(0.09)	(0.59)
Incomenlw	1.40E-04***	5.61E-04***	6.75E-04***
	(3.76E-05)	(1.73E-04)	(2.25E-04)
Age	0.024***	0.036***	-0.004
	(0.01)	(0.01)	(0.02)
Agesquared	-1.66E-04**	-2.47E-04***	-9.32E-05
	(6.73E-05)	(6.18E-05)	(1.99E-04)
Aleveldum	0.059*	0.123***	-0.296***
	(0.04)	(0.03)	(0.11)
Degreedum	0.055	0.109**	-0.062
	(0.05)	(0.04)	(0.15)
Pensiondum	0.075*	0.104**	-0.017
	(0.04)	(0.04)	(0.14)
Sexdum	0.064**	0.041	0.202**
	(0.03)	(0.03)	(0.10)
Maritaldum	0.049	0.070*	-0.352***
	(0.04)	(0.04)	(0.11)
Childdum	0.038	-0.018	0.400***
	(0.04)	(0.05)	(0.14)
Londondum	-0.014	0.003	-0.140
	(0.05)	(0.04)	(0.15)
constant	-1.170***	-1.510***	

	(0.14)	(0.17)
Log likelihood	-2051.1895	-1945
No. of observations	2558	2558
left-censored observations at α2000<=0	1294	1294
uncensored observations	1105	1105
right-censored observations at α2000>=1	159	159

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 8:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the non-house owner subsample in 1995 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	 γ
Dum early retirement	-0.524	-0.186	-0.200
	(0.39)	(0.37)	(1.29)
Dum normal retirement	-0.160	-0.020	-0.058
	(0.20)	(0.21)	(0.57)
Net liquid wealth	2.167***	1.676***	-0.937*
	(0.40)	(0.27)	(0.53)
Net liquid wealth squared	-0.638***	-0.453***	
	(0.16)	(0.09)	
Personaldebt	3.403	-28.402*	48.757***
	(2.20)	(14.55)	(13.87)
Outstanding mortgage loans	-0.694	-0.044	-1.609
	(0.60)	(0.53)	(1.38)
Gross labour income	-1.944**	-0.463	1.497
	(0.90)	(1.48)	(3.41)
Incomenlw	4.63E-05	9.43E-04	0.002**
	(5.47E-05)	(6.38E-04)	(8.60E-04)
Age	0.027**	0.033**	-0.021
	(0.01)	(0.01)	(0.03)
Agesquared	-1.84E-04	-2.09E-04	1.20E-04
	(1.39E-04)	(1.47E-04)	(3.56E-04)
Aleveldum	0.119	0.316***	-0.384
	(0.13)	(0.12)	(0.30)
Degreedum	0.204	-0.259	0.745
	(0.15)	(0.33)	(0.49)
Pensiondum	0.211*	0.266	-0.625**
	(0.12)	(0.17)	(0.34)
Sexdum	0.091	0.120	-0.200
	(0.09)	(0.09)	(0.23)
Maritaldum	0.083	0.090	0.157
	(0.09)	(0.09)	(0.25)
Childdum	0.115	-0.477	1.452***
	(0.13)	(0.34)	(0.46)
Londondum	0.274**	0.116	0.333
	(0.12)	(0.20)	(0.44)
constant	-1.483***	-1.713***	
	(0.33)	(0.42)	
Log likelihood	-545.0980	-494.4344	
No. of observations	829	829	
left-censored observations at α2000<=0	598	598	

uncensored observations	184	184
right-censored observations at α2000>=1	47	47

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 9:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the whole sample in 2000 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	Heteroscedastic Tobit $\boxed{\gamma}$
Dum early retirement	0.139**	0.122**	-0.060
	(0.06)	(0.05)	(0.18)
Dum normal retirement	0.098*	0.097*	-0.052
	(0.06)	(0.05)	(0.17)
Net liquid wealth	1.016***	1.172***	-1.827***
	(0.07)	(0.10)	(0.21)
Net liquid wealth squared	-0.222***	-0.456***	0.738***
	(0.02)	(0.05)	(0.08)
Personaldebt	1.773***	1.852***	1.945*
	(0.22)	(0.43)	(1.15)
Housing	0.209***	0.324***	-0.716***
	(0.03)	(0.04)	(0.10)
Housing squared	-0.034***	-0.065***	0.116***
	(0.01)	(0.01)	(0.03)
Outstanding mortgage loans	0.073*	0.106***	0.241**
	(0.04)	(0.04)	(0.12)
Gross labour income	0.033	-0.201**	-0.450
	(0.13)	(0.09)	(0.33)
Incomenlw	-2.57E-05	-1.46E-04*	1.45E-04
	(1.72E-05)	(8.31E-05)	(9.50E-05)
Age	0.029***	0.036***	-0.022*
	(4.40E-03)	(5.32E-03)	(0.01)
Agesquared	-2.43E-04***	-3.00E-04***	1.89E-04
	(4.51E-05)	(5.32E-05)	(1.37E-04)
Aleveldum	0.067**	0.077***	-0.226***
	(0.03)	(0.03)	(0.08)
Degreedum	0.055	0.081***	-0.291***
	(0.04)	(0.03)	(0.10)
Pensiondum	0.134***	0.179***	-0.233**
	(0.03)	(0.04)	(0.10)
Sexdum	0.071***	0.034	0.108
	(0.02)	(0.02)	(0.07)
Maritaldum	0.016	0.032	-0.219***
	(0.03)	(0.03)	(0.08)
Childdum	0.053	0.016	0.350***
	(0.03)	(0.04)	(0.10)
Londondum	0.036	-0.007	0.082
	(0.05)	(0.04)	(0.13)
constant	-1.190***	-1.475***	
	(0.10)	(0.13)	

Log likelihood	-4073.1477	-3873
No. of observations	4927	4927
left-censored observations at α2000<=0	2505	2505
uncensored observations	2036	2036
right-censored observations at α2000>=1	386	386

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 10:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the house-owner subsample in 2000 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	γ
Dum early retirement	0.126**	0.119**	-0.041
	(0.06)	(0.06)	(0.19)
Dum normal retirement	0.078	0.090*	-0.138
	(0.06)	(0.05)	(0.18)
Net liquid wealth	0.914***	1.092***	-1.851***
	(0.06)	(0.10)	(0.22)
Net liquid wealth squared	-0.200***	-0.418***	0.743***
	(0.02)	(0.05)	(0.08)
Personaldebt	1.614***	1.721***	1.505
	(0.21)	(0.41)	(1.21)
Housing	0.160***	0.206***	-0.593***
	(0.03)	(0.04)	(0.13)
Housing squared	-0.026***	-0.038***	0.085***
	(0.01)	(0.01)	(0.03)
Outstanding mortgage loans	0.082**	0.109***	0.310**
	(0.04)	(0.04)	(0.13)
Gross labour income	0.054	-0.163*	-0.428
	(0.12)	(0.09)	(0.34)
Incomenlw	-6.35E-05*	-1.29E-04*	7.00E-05
	(3.76E-05)	(7.82E-05)	(8.50E-05)
Age	0.027***	0.037***	-0.041***
	(4.79E-03)	(5.59E-03)	(1.5E-02)
Agesquared	-2.19E-04***	-3.02E-04***	3.86E-04**
	(4.96E-05)	(5.61E-05)	(1.56E-04)
Aleveldum	0.032	0.062**	-0.263***
	(0.03)	(0.03)	(0.09)
Degreedum	0.038	0.065**	-0.321***
	(0.04)	(0.03)	(0.11)
Pensiondum	0.114***	0.147***	-0.216**
	(0.03)	(0.04)	(0.11)
Sexdum	0.061***	0.041*	0.058
	(0.02)	(0.02)	(0.08)
Maritaldum	0.010	0.008	-0.157*
	(0.03)	(0.03)	(0.09)
Childdum	0.051	0.052	0.277**
	(0.03)	(0.03)	(0.11)
Londondum	-0.007	-0.011	0.003
	(0.05)	(0.04)	(0.15)
constant	-1.070***	-1.368***	

	(0.11)	(0.14)
Log likelihood	-3196.6976	-3044
No. of observations	3807	3807
left-censored observations at α2000<=0	1695	1695
uncensored observations	1815	1815
right-censored observations at α2000>=1	297	297

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 4. 11:The standard homoscedastic Tobit and heteroscedastic Tobit estimations for the non-house owner subsample in 2000 of BHPS data

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	γ
Dum early retirement	0.282	0.302	-0.050
	(0.34)	(0.86)	(1.41)
Dum normal retirement	0.300	0.325	0.201
	(0.22)	(0.36)	(0.59)
Net liquid wealth	2.303***	1.678***	-1.755**
	(0.44)	(0.23)	(0.69)
Net liquid wealth squared	-0.514***	-0.328**	
	(0.14)	(0.08)	
Personaldebt	2.581	-1.196	8.017*
	(1.73)	(2.78)	(4.83)
Outstanding mortgage loans	0.550	0.801*	-0.259
	(0.48)	(0.43)	(0.75)
Gross labour income	0.268	0.673	-1.214
	(0.91)	(1.00)	(1.98)
Incomenlw	5.68E-07	-1.35E-04	2.01E-04
	(3.82E-05)	(2.50E-04)	(2.46E-04)
Age	0.034**	-0.004	0.075**
	(0.01)	(0.02)	(0.04)
Agesquared	-3.23E-04**	3.67E-05	-7.39E-04*
	(1.42E-04)	(2.37E-04)	(4.14E-04)
Aleveldum	0.353***	0.440***	-0.238
	(0.13)	(0.16)	(0.32)
Degreedum	0.181	0.179	-0.290
	(0.16)	(0.21)	(0.41)
Pensiondum	0.254**	0.523***	-0.660**
	(0.13)	(0.19)	(0.32)
Sexdum	0.149	0.071	0.371
	(0.09)	(0.15)	(0.27)
Maritaldum	-0.009	0.260*	-0.685***
	(0.10)	(0.14)	(0.26)
Childdum	0.115	-0.269	0.879**
	(0.14)	(0.23)	(0.36)
Londondum	0.242	0.251	0.230
	(0.15)	(0.23)	(0.42)
constant	-1.973***	-1.257***	
	(0.36)	(0.46)	
Log likelihood	-795.2617	-775.8333	
No. of observations	1120	1120	
left-censored observations at α2000<=0	810	810	

uncensored observations	221	221
right-censored observations at α2000>=1	89	89

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

In previous Table 4.4, we estimate two separate models for house owners and non-house owners. Now, we set up a dummy variable for house owners and interact this dummy variable with other explanatory variables by using the full sample, so that we are able to examine the effects of each repressor on the risky asset holdings of house owners and non-house owners respectively. In addition, this section can be regarded as providing robustness test for our previous results. The new results are presented in the following Table 4.12 and Table 4.13. We also present the results for 2000 in the appendix as Table (D) and Table (E).

The model 1 in Table 4.12 is the main specification. As we can see, for non-house owners, after controlling for other social and economical factors, neither early retirement nor normal retirement has an impact on portfolio share of risky assets. However, the coefficient of *dumearlyretirementdumhousing* is 0.633, which is positive and statistically significant. This confirms what we find and conclude in previous Table 4.4 that early retirement has positive impact on risky asset holdings for house owners. In the model 2 of Table 4.12, we include variables on the number of children aged below 15 in the family (*numberofkids*) and variables on the health of the individual (*healthstatus*[32]). The marginal effects for model 2 are also reported in Table 4.12. The marginal effects measure the expected change in risky asset share as a function of one unit increase in the explanatory variable. The second column presents the value of dy/dx and the third column presents the average value of the explanatory variable. As we can see in the third column, compared with non-house owners, the early retirement increase the proportion of net wealth invested in risky assets by 30.3percentage point for house owners in 1995. In other words, the expected/predicted portfolio share would increase from 19.65 percent[33] to 49.95 percent.

Now we look at model 1 and model 2, we find the net liquid wealth still has an inverse-U shape impact on risky asset holdings for both house owners and non-house owners. The third column reveals that if average net liquid wealth increases by £100,000, the expected/predicted risky asset share would increase by 47.9 percentage point for non-house owners and increase by 17 percentage point for house owners.

The personal debt has same positive impact on risky asset holdings for both house owners and non-house owners as we can see in model 1 and model 2. An increase of £100,000 in personal debt would result in an increase of 112.2 percentage point in expected risky asset share for both house owners and non-house owners as we can see in the third column.

Because only house owners have gross house value, we do not interact *housing* and *housingsquared* with *dumhousing*. The gross house value has an inverse-U shape impact on risky asset share for house owners as we can see in model 1 and model 2. An

[32] The healthstatus equals 1, 2, 3, 4, 5 if the individual reported excellent health; good health, fair health, poor health, and very poor health respectively.

[33] Please note this predicted portfolio share is not presented in the Table 4.12. It is part of the results we obtain when estimating the marginal effects after Tobit

increase of £100,000 in gross house value would result in an increase of 10.3 percentage point in expected risky asset share for house owners.

The gross labour income has a negative impact on risky asset holdings for non-house owners and has a positive impact for house owners as we can see in model 1 and model 2. , As we can see in the third column, an increase of £100,000 in gross labour income would result in an decrease of 58.9 percentage point in expected risky asset share for non-house owners whereas it would results in an increase of 9.3 percentage point in expected risky asset share for house-owners. This could reveal that housing actually act as a financial security for individuals. If individuals are house owners, then they are more willing to increase their risky portfolio as their labour income increase.

The ratio of labour income to net liquid wealth has a positive impact on risky asset holdings for both house owners as we can see in model 1 and model 2. The third column reveals that the marginal effect of *incomenlw* on risky asset share is close to zero but is positive and significant for house owners.

Age has same inverse-U shape impact on risky asset holdings for both house owners and non-house owners as we can in model 1 and model 2. An increase of 10 years in average age would increase the expected risky asset share by 8.38 percentage point for both house owners and non-house owners as we can in the third column in Table 4.12.

Pensiondum has same positive impact for both house owners and non-house owners as we can see in model 1 and model 2. Compared with individuals without participating in neither employer's pension scheme nor private personal pension scheme, individuals who participate would invest 6.4 percentage point higher. This is revealed in the third column.

Londondum has a positive impact for non-house owners and has negative impact for house owners as we can see in model 1 and model 2. The third column suggests that for non-house owners, living in London would increase the risky asset share by 9.2 percentage point. For house owners, living in London would increase the risky asset share by 1.4 percentage point.

Table 4. 12: Models with interaction terms, marginal effects and robustness test (1995)

	Model 1	Model 2	marginal effect for model 2	
Varibles			**dy/dx**	**X**
Dumearlyretirement	-0.415	-0.411	-0.120	0.025
	(0.29)	(0.29)	(0.08)	
Dumnormalretirement	-0.114	-0.118	-0.043	0.221
	(0.15)	(0.15)	(0.05)	
Netliquidwealth	1.749***	1.784***	0.677***	0.110
	(0.29)	(0.29)	(0.11)	
Netliquidwealthsquared	-0.509***	-0.521***	-0.198***	0.197
	(0.12)	(0.12)	(0.04)	
Personaldebt	2.938*	2.956*	1.122*	0.011
	(1.62)	(1.62)	(0.61)	
Housing	0.302***	0.308***	0.117***	0.536
	(0.07)	(0.07)	(0.03)	
Housingsquared	-0.035*	-0.036**	-0.014**	0.530
	(0.02)	(0.02)	(0.01)	
Outstandingmortgage	-0.571	-0.582	-0.221	0.204
	(0.45)	(0.45)	(0.17)	
Grosslabourincome	-1.514**	-1.552**	-0.589**	0.106
	(0.65)	(0.66)	(0.25)	
Incomenlw	3.84E-05	3.55E-05	1.35E-05	32.291
	(4.02E-05)	(4.05E-05)	(2.00E-05)	
Age	0.025***	0.023***	0.009***	45.535
	(0.01)	(0.01)	(2.57E-03)	
Agesquared	-1.87E-04**	-1.63E-04**	-6.18E-05**	2414.870
	(7.56E-05)	(7.76E-05)	(3.00E-05)	
Aleveldum	0.095	0.092	0.036	0.239

	(0.09)	(0.09)	(0.04)	
Degreedum	0.168	0.170	0.069	0.126
	(0.11)	(0.11)	(0.05)	
Pensiondum	0.162*	0.167*	0.064*	0.480
	(0.09)	(0.09)	(0.03)	
Sexdum	0.075	0.075	0.028	0.488
	(0.06)	(0.06)	(0.02)	
Maritaldum	0.060	0.064	0.024	0.571
	(0.07)	(0.07)	(0.03)	
Childdum	0.107	0.064	0.025	0.217
	(0.10)	(0.15)	(0.06)	
Numberofkids		0.021	0.008	0.490
		(0.07)	(0.02)	
Londondum	0.223**	0.221**	0.092**	0.100
	(0.09)	(0.09)	(0.04)	
Healthstatus		0.025	0.009	2.070
		(0.03)	(0.01)	
Dumearlyretirementdumhousing	0.633**	0.627**	0.303**	0.021
	(0.30)	(0.30)	(0.15)	
Dumnorretirementdumhousing	0.158	0.171	0.069	0.146
	(0.17)	(0.17)	(0.07)	
Netliquidwealthdumhousing	-1.241***	-1.286***	-0.488***	0.099
	(0.29)	(0.30)	(0.11)	
Nlwsquareddumhousing	0.458***	0.471***	0.179***	0.186
	(0.12)	(0.12)	(0.04)	
Personaldebtdumhousing	-1.527	-1.518	-0.576	0.009
	(1.72)	(1.73)	(0.66)	
Outstandingmdumhousing	0.614	0.625	0.237	0.201
	(0.45)	(0.45)	(0.17)	
Grosslabourincomedumhousing	1.769***	1.796***	0.682***	0.088
	(0.68)	(0.68)	(0.26)	
Incomenlwdumhousing	1.07E-04*	1.11E-04*	4.21E-05*	18.192
	(5.66E-05)	(5.68E-05)	(2.00E-05)	
Agedumhousing	-0.002	0.003	0.001	34.116
	(4.98E-03)	(0.01)	(2.26E-03)	
Agesquareddumhousing	3.15E-05	-1.35E-05	-5.11E-06	1765.040
	(7.34E-05)	(7.86E-05)	(3.00E-05)	
Aleveldumdumhousing	-0.035	-0.033	-0.012	0.203
	(0.10)	(0.10)	(0.04)	
Degreedumdumhousing	-0.111	-0.113	-0.041	0.097
	(0.12)	(0.12)	(0.04)	
Pensiondumdumhousing	-0.085	-0.094	-0.035	0.407
	(0.10)	(0.10)	(0.04)	
Sexdumdumhousing	-0.011	-0.011	-0.004	0.375

	(0.07)	(0.07)	(0.03)	
Maritaldumdumhousing	-0.006	-0.014	-0.005	0.485
	(0.08)	(0.08)	(0.03)	
Childdumdumhousing	-0.068	0.052	0.020	0.179
	(0.10)	(0.16)	(0.06)	
Numberofkidsdumhousing		-0.068	-0.026	0.392
		(0.07)	(0.03)	
Londondumdumhousing	-0.237**	-0.234**	-0.078***	0.068
	(0.10)	(0.10)	(0.03)	
Healthstatusdumhousing		-0.050	-0.019	1.526
		(0.04)	(0.01)	
Constant	-1.193***	-1.178***		
	(0.13)	(0.13)		
Log likelihood	-2611.15	-2608.83		
LR chi2	593.52	598.17		
Pro>chi2	0	0		
Pseudo R2	0.1021	0.1029		
No. of observations	3387	3387		
left-censored observations at α2000<=0	1892	1892		
uncensored observations	1289	1289		
right-censored observations at α2000>=1	206	206		

*,**,*** *indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage and Grosslabourincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

In addition to the Tobit regressions we discuss in the above, in the following Table 4.13, we regress on *permanent income*[34] and *permanentincomenlw* in model 3. For comparison, we also regress on *gross labour income* and *incomenlw* in model 4 using the same sample data as in model 3. Finally, we regress probit specification and report it as model 5 in Table 4.13.

As we can see, in terms of sign and significance level, there is no difference between model 3 and model 4 except for the following repressors. The model 3 suggests that outstanding mortgage has a negative impact on risky asset share for non-house owners and it has a positive impact for house-owners. The ratio of permanent income to net liquid wealth has a positive impact for house-owners although the coefficient is close to zero. *Londondum* has no impact for both house-owners and non-house owners. However, we still find the positive impact of early retirement on risky asset share for house-owners, which is robust to our previous findings in Table 4.4.

Similar to the Tobit regressions, the Probit regression in Table 4.13 also include variables on the number of children aged below 15 in the family (*numberofkids*) and variables on the health of the individual (*healthstatus*). The Probit regression uses 3387 observations which is the same as tobit regression in model 1 and model 2 of Table 4.12. In terms of sign and significance level, there is no difference between this Probit model in Table 4.13 and Tobit models in Table 4.12 except for the following repressors. As we

[34] The way we construct Permanentincome and *Permanentincomenlw* is similar to the way we construct them in Chapter 3. We follow Guariglia's (2001) approach to obtain the value of permanent income for individuals whose age is between 21 and 65. We use the BHPS data in 1995 and 2000, and we, firstly, run a random effect model by regressing individuals' gross labour income on "age, age squared, education dummies, occupational dummies, and interactions of the latter two groups of dummies with age and age squared" (Guariglia, 2001, p627). Then we use the estimated coefficients to predict the permanent income for individuals in 1995 and 2000 respectively. Finally, we divide permanent income by net liquid wealth to get the ratio. The reason why we regress on Permanentincome and *Permanentincomenlw* is that we recognise gross labour income is potentially endogenous which may lead to inconsistent estimators.

can see in the Probit model of Table 4.13, early retirement has a negative impact on probability of a non-house owner investing in risky assets, and it has a positive impact on probability of a house owner investing in risky assets. *Personaldebt* has no impact on the probability of an individual investing in risky assets.

Table 4. 13: Table 4.12 continued

Varibles	**Model 3** **regress on *pincome, pincomenlw***	**Model 4** **compare with model 3**	**Model 5** **probit**
Dumearlyretirement	-0.328	-0.464	-0.802*
	(0.33)	(0.34)	(0.48)
Dumnormalretirement	-0.097	-0.173	-0.236
	(0.24)	(0.24)	(0.25)
Netliquidwealth	3.727***	3.726***	4.860***
	(0.64)	(0.64)	(0.71)
Netliquidwealthsquared	-2.118***	-2.121***	-1.393***
	(0.47)	(0.47)	(0.31)
Personaldebt	5.478***	5.561***	4.518
	(1.94)	(1.93)	(2.85)
Housing	0.444***	0.439***	0.465***
	(0.09)	(0.09)	(0.14)
Housingsquared	-0.075***	-0.073***	-0.067*
	(0.03)	(0.03)	(0.04)
Outstandingmortgage	-0.998*	-0.709	-0.765
	(0.51)	(0.52)	(0.75)
Grosslabourincome		-1.676**	-2.698**
		(0.75)	(1.13)
Incomenlw		3.16E-05	2.64E-05
		(4.76E-05)	(6.63E-05)
Permanentincome	-1.595		
	(1.45)		
Permanetincomenlw	0.0000871		
	(7.46E-05)		
Age	0.017	0.015	0.039***
	(0.02)	(0.02)	(0.01)
Agesquared	-0.00014	-1.19E-04	-2.64E-04**
	(2.24E-04)	(2.11E-04)	(1.30E-04)
Aleveldum	0.066	0.057	0.223
	(0.12)	(0.11)	(0.15)
Degreedum	0.261	0.164	0.219
	(0.18)	(0.13)	(0.19)
Pensiondum	0.085	0.152	0.275*
	(0.09)	(0.10)	(0.15)
Sexdum	0.054	0.109	0.139
	(0.09)	(0.09)	(0.11)
Maritaldum	0.080	0.083	0.107
	(0.10)	(0.10)	(0.11)

Childdum	-0.040	-0.070	0.073
	(0.17)	(0.17)	(0.25)
Numberofkids	0.088	0.098	-0.056
	(0.08)	(0.08)	(0.11)
Londondum	0.194	0.239*	0.360**
	(0.12)	(0.13)	(0.16)
Healthstatus	0.045	0.048	0.031
	(0.05)	(0.05)	(0.06)
Dumearlyretirementdumhousing	0.515*	0.677*	1.200**
	(0.31)	(0.35)	(0.54)
Dumnorretirementdumhousing	0.153	0.241	0.366
	(0.27)	(0.27)	(0.29)
Netliquidwealthdumhousing	-3.244***	-3.250***	-1.335*
	(0.64)	(0.64)	(0.77)
Nlwsquareddumhousing	2.071***	2.073***	1.077***
	(0.47)	(0.47)	(0.31)
Personaldebtdumhousing	-4.082**	-4.204**	-0.357
	(2.05)	(2.04)	(3.07)
Outstandingmdumhousing	1.047**	0.746	0.697
	(0.51)	(0.53)	(0.75)
Grosslabourincomedumhousing		1.876**	3.823***
		(0.78)	(1.22)
Incomenlwdumhousing		1.24E-04*	2.29E-04*
		(6.44E-05)	(1.18E-04)
Permanentincomedumhousing	2.201		
	(1.60)		
Permanetincomenlwdumhousing	2.58E-04**		
	(1.10E-04)		
Agedumhousing	0.002	0.005	0.003
	(0.01)	(0.01)	(0.01)
Agesquareddumhousing	4.64E-05	-5.74E-07	-3.32E-05
	(1.86E-04)	(1.66E-04)	(1.37E-04)
Aleveldumdumhousing	-0.007	0.021	-0.144
	(0.13)	(0.12)	(0.17)
Degreedumdumhousing	-0.223	-0.080	-0.113
	(0.20)	(0.14)	(0.21)
Pensiondumdumhousing	-0.017	-0.092	-0.174
	(0.10)	(0.11)	(0.17)
Sexdumdumhousing	0.044	-0.022	-0.110
	(0.10)	(0.10)	(0.12)
Maritaldumdumhousing	-0.024	-0.028	0.055
	(0.11)	(0.11)	(0.13)
Childdumdumhousing	0.153	0.181	0.112
	(0.19)	(0.19)	(0.27)

Numberofkidsdumhousing	-0.145*	-0.154*	-0.078
	(0.08)	(0.08)	(0.12)
Londondumdumhousing	-0.219	-0.268*	-0.353*
	(0.14)	(0.14)	(0.18)
Healthstatusdumhousing	-0.072	-0.073	-0.085
	(0.06)	(0.06)	(0.06)
Constant	-1.148***	-1.132***	-1.982***
	(0.25)	(0.25)	(0.22)
Log likelihood	-2026.27	-2028.20	-1860.02
LR chi2	426.15	422.31	928.69
Pro>chi2	0	0	0
Pseudo R2	0.0952	0.0943	0.1998
No. of observations	2573	2573	3387
left-censored observations at α2000<=0	1473	1473	
uncensored observations	925	925	
right-censored observations at α2000>=1	175	175	

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage,Grosslabourincome, and Permanentincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

4.5.2 Simple DD estimation

Before we run the simple DD estimation by using the Tobit method to estimate the impact of retirement on the portfolio allocation for the elderly, which we have discussed in the above section, we will manually calculate the DD estimates and run the simple DD estimation by OLS first in order to understand the DD concept. The following Table 4.14, Table 4.15 and Table 4.16 presents the simple DD estimates by using the whole sample, house owner subsample and non-house owner subsample respectively. We first look at Table 4.14. As we can see, the change in the portfolio share for the treatment group in the whole sample over 1995 and 2000 is PA4-PA3=0.05 where PA stands for portfolio allocation. Under the “common trends” assumption, some of this change may attribute to the changes in the labour force participation status and the other part of this change is due to external factors for example changes in expected return. These external non-retirement factors are reflected by the change in the portfolio share for the control group over 1995 and 2000, which is PA2-PA1=0.03 reported in the Table 4.14. Finally, an estimate of the impact of retirement on the portfolio allocation in the treatment group in the whole sample is (PA4-PA3)-(PA2-PA1)= 0.02. In other words, basically we need to compare the portfolio share change of individual who experienced the change in their labour force participation status with that of individuals who faced no changes, under the assumption that they would have reallocated their portfolio share in the same way and same amount in the absence of the labour force participation status change between 1995 and 2000. The explanation for Table 4.15 and Table 4.16 follows the same logic. The only difference is that the results in Table 4.15 are based on the house owner subsample whereas the results in Table 4.16 are based on the non-house owner subsample.

Table 4. 14: Simple DD illustration for the whole sample

	Control group (*dumtreatment*=0)		Treatment group (*dumtreatment*=1)	
1995 (*timedummy*=0)	0.28	[0.01]	0.36	[0.04]
2000 (*timedummy*=1)	0.31	[0.01]	0.41	[0.12]
Difference	0.03	[0.04]	0.05	[0.04]
Difference-in-Difference			0.02	

Note: The standard errors are presented in square brackets.

Table 4. 15:Simple DD illustration for house owner subsample

	Control group *(dumtreatment=0)*		Treatment group *(dumtreatment=1)*	
1995 *(timedummy=0)*	0.28	[0.01]	0.39	[0.04]
2000 *(timedummy=1)*	0.32	[0.01]	0.41	[0.04]
Difference	0.04	[0.02]	0.02	[0.05]
Difference-in-Difference			-0.02	

Note: The standard errors are presented in square brackets.

Table 4. 16:Simple DD illustration for non house owner subsample

	Control group *(dumtreatment=0)*		Treatment group *(dumtreatment=1)*	
1995 *(timedummy=0)*	0.22	[0.04]	0.19	[0.09]
2000 *(timedummy=1)*	0.20	[0.04]	0.41	[0.12]
Difference	-0.02	[0.04]	0.22	[0.12]
Difference-in-Difference			0.24	

Note: The standard errors are presented in square brackets.

The pitfall of using this method to obtain DD estimates is that we do not know whether these estimates are statistically significant or not. Therefore, we run a simple DD regression by OLS estimation and report the estimation results in Table 4.17. As we can see that the coefficients for *Timedummy*Dumtreatment* in each model are the same as the DD estimates in the above Table 4.14, Table 4.15 and Table 4.16 respectively. However, these coefficients *Timedummy*Dumtreatment* are not statistically significant.

Table 4. 17:Simple DD estimation for different samples by OLS

	Coefficients		
Variables	Model 1	Model 2	Model 3
	(whole sample)	(house owner subsample)	(non houseowner sample)
Dumtreatment	0.081*	0.104**	-0.034
	(0.04)	(0.05)	(0.11)
Timedummy	0.031*	0.038**	-0.028
	(0.02)	(0.02)	(0.05)
Timedummy*Dumtreatment	0.019	-0.018	0.246
	(0.06)	(0.06)	(0.15)
Constant	0.275***	0.281***	0.224***
	(0.01)	(0.01)	(0.04)
F	4.44	4.41	1.36
Prob > F	0.0041	0.0042	0.2558
R-squared	0.0067	0.0074	0.0189
Adj R-squared	0.0052	0.0058	0.0050
No.of observations	1986	1770	216

Finally, we run a simple DD regression in a Tobit model for each sample and report the estimation results in Table 4.18. As we can see, in each sample, the number of observations which are left-censored at zero is much higher than that of observations which are right-censored at one. The coefficient of *timedummydumtreatment* is 0.02, -0.04, 0.64 for the whole sample, house owner subsample and non-house owner subsample respectively. However, none of these coefficients are statistically significant and the values of Pseudo R^2 in these three models are all very low, which confirms that we have to augment this simple DD estimation with regression-adjusted DD estimation by controlling for relevant and observable factors in order to estimate whether the changes in labour force participation status has an impact on generating the difference between the changes in average portfolio share of the two groups over 1995 and 2000.

Table 4. 18:Simple DD estimation in tobit for different samples

	Coefficients		
Variables	Model 1 (whole sample)	Model 2 (house owner subsample)	Model 3 (non houseowner sample)
Dumtreatment	0.206***	0.239***	0.007
	(0.08)	(0.08)	(0.32)
Timedummy	0.078**	0.091***	-0.122
	(0.03)	(0.03)	(0.16)
Timedummy*Dumtreatment	0.024	-0.039	0.640
	(0.11)	(0.11)	(0.44)
Constant	0.060**	0.084***	-0.233*
	(0.02)	(0.02)	(0.12)
LR chi2(3)	22.85	23.08	4.59
Prob > chi2	0	0	0.2043
Pseudo R2	0.0063	0.0072	0.0121
Log likelihood	-1794.1764	-1585.3975	-188.0772
No. of observations	1986	1770	216
left-censored observations at α2000<=0	837	707	130
uncensored observations	1005	939	66
right-censored observations at α2000>=1	144	124	20

4.5.3 Regression-adjusted DD estimation

In this section, three regression-adjusted DD estimations in Tobit have been implemented and all the estimates are reported in Table 4.19. In the first model and second model, we regress the portfolio share on all variables. While in the third model, we regress the portfolio share on all variables except *housing* and *housingsquared* because for the respondents in this model they have zero housing values.

As we can see from the Table 4.19, for the second model in which we use all the house owners as our sample, the coefficient for the treatment dummy variable *dumtreatment* is positive but not statistically significant. The *timedummy* is negative but not statistically significant neither. Since *dumtreatment* "captures possible differences between the treatment and the control groups prior to" the labour force participation status change, and the *timedummy* "captures aggregate factors that would cause changes in portfolio share even in the absence of" labour force participation status change, the coefficient on the interaction of the treatment and time dummies is in our interests, which reveals a positive impact of retirement on portfolio shares in risky assets, but it is not statistically significant. However, we found that age has an inversed-U shape impact and it is statistically significant. The age reaches it maximum effect at age 74, which is older than the normal retirement age which is 60 for female and 65 for male. Hence, our explanation why retirement itself does not have a significant impact on changes in the elderly' risky asset allocation is that even the elderly is retired, house ownership can still serve as an insurance policy for him/her which provide extra financial security and it encourages individual to take higher risk by allocating a higher proportion of financial wealth in risky assets.

In the third model in which we use all the non-house owners subsample, we can see that in this case actually the involvement in public or/and private pension schemes serves as an insurance policy rather than house ownership. Respondents who do participate in any pension schemes would invest 43 percentage points higher than respondents with no participation. This positive impact of involvement in pension schemes on risky asset allocation not only is big in magnitude but also is statistically significant.

As expected, personal debt, being male and gross income has positive impact on portfolio share in risky assets. Table 4.19 reveals an inversed-U shape impact of net financial wealth on portfolio allocations. Similar patterns of the impact can be found on the effect of gross housing value and age. In terms of the impact of housing ownership, we find that in model two, owning a housing asset contributes 24 percentage point increase in risky asset holdings and this is statistically significant at the 1 percentage significance level.

Table 4.20, 4.21, 4.22 present the results for homoscedastic Tobit and heteroscedastic Tobit regression-adjusted DD estimation. Table 4.20 is the results for the whole sample, Table 4.21 is for the house-owner subsample, and Table 4.22 is for the non-house owner subsample. The signs for the coefficients in homoscedastic Tobit and heteroscedastic Tobit regression-adjusted DD estimation are the same for the whole sample and house-owner subsample, whereas the signs are different for the non-house owner subsample, as we can see in Table 22.

To sum up, based on the heteroscedastic Tobit regression-adjusted DD estimation that are reported in Table 4.20, 4.21, 4.22, we find retirement has no effect on risky asset shares either for house owners or for non-house owners. This could be due to the small sample size we use here. We drop the observations when there is a missing value for our independent variable or any control variable, therefore our treatment group consists of 86 respondents and control group consists of 907 respondents, which give us 993 respondents in total. In our earlier research, we have fewer control variables; hence the sample size is bigger. If we control for age, gender, gross income, gross housing value, net liquid wealth and personal debt only, then our treatment group consists of 106 respondents and control group consists of 1447 respondents, which give us 1553 respondents in total. And in this earlier research, by using DD estimation we have found a positive effect of retirement on risky asset shares. This positive effect is significantly different from zero at the 5 percentage level. These earlier results have been reported in Table 4.23. As we can see in Table 4.23, three regression-adjusted DD models have been estimated. The way in which these three models are different from each other are how we control for the housing effect. In model 1, we regress the risky asset share on the gross housing value and its squared term. While in model 2, we regress on variable of *dumhousing* which indicates the ownership of a housing asset. In model 3, we include all these three housing related variables. Since *dumtreatment* "captures possible differences between the treatment and control groups prior to" the labour force participation status change, and the *timedummy* "captures aggregate factors that would cause changes in portfolio share even in the absence of " labour force participation status change, the coefficient on the interaction of the treatment and time dummies is our interests, which reveals a positive impact of retirement on portfolio shares in risky assets, and it is statistically significant under all three models. In terms of the impact of house ownership, we find that in model 2, owning a housing asset contributes 24 percent point increase in risky asset shares and this is significantly different from zero at 1 percentage level.

Table 4. 19:Results for regression-adjusted DD estimation using 1995 and 2000 of BHPS data

	Coefficients		
Variables	Model 1: total sample	Model 2:house owner sample	Model 3:non house owner sample
Dumtreatment	0.036	0.053	-0.028
	(0.08)	(0.08)	(0.31)
Timedummy	-0.040	-0.027	-0.253
	(0.03)	(0.03)	(0.16)
Timedummy*Dumtreatment	0.127	0.049	0.694*
	(0.11)	(0.11)	(0.40)
Net liquid wealth	0.652***	0.616***	2.678
	(0.08)	(0.08)	(1.93)
Net liquid wealth squared	-0.115***	-0.108***	-2.338
	(0.02)	(0.02)	(3.79)
Personaldebt	1.738***	1.634***	2.863
	(0.39)	(0.39)	(4.12)
Housing	0.089*	0.099*	
	(0.05)	(0.06)	
Housing squared	-0.016	-0.017	
	(0.01)	(0.01)	
Outstanding mortgage loans	0.274***	0.283***	-0.210
	(0.06)	(0.06)	(1.07)
Gross labour income	-0.058	-0.023	-2.565**
	(0.14)	(0.13)	(1.30)
Incomenlw	1.03E-04***	7.33E-05*	3.29E-04
	(3.41E-05)	(4.10E-05)	(2.22E-04)
Age	0.024**	0.024**	0.023
	(0.01)	(0.01)	(0.03)
Agesquared	-1.62E-04	-1.63E-04	-1.43E-04
	(1.10E-04)	(1.18E-04)	(3.86E-04)
Aleveldum	0.041	0.007	0.614***
	(0.04)	(0.04)	(0.20)
Degreedum	0.071	0.046	0.271
	(0.04)	(0.05)	(0.24)
Pensiondum	0.036	0.012	0.428**
	(0.04)	(0.04)	(0.18)
Sexdum	0.116***	0.125***	0.102
	(0.03)	(0.03)	(0.15)
Maritaldum	-0.018	-0.019	-0.016
	(0.04)	(0.04)	(0.16)
Childdum	0.154***	0.121***	0.781***
	(0.04)	(0.04)	(0.21)
Londondum	0.028	0.002	0.442*

	(0.05)	(0.05)	(0.23)
constant	-0.939***	-0.897***	-1.301*
	(0.19)	(0.21)	(0.71)
Log likelihood	-1660.2781	-1473.3759	-161.0764
LR chi2	290.65	247.12	58.59
Pro>chi2	0	0	0
Pseudo R2	0.0805	0.0774	0.1539
No. of observations	1986	1770	216
left-censored observations at α2000<=0	837	707	130
uncensored observations	1005	939	66
right-censored observations at α2000>=1	144	124	20

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table 4. 20:Results for Homoscedastic Tobit and Heteroscedastic Tobit regression-adjusted DD estimation, the whole sample

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	γ
Dumtreatment	0.036	0.094	-0.351
	(0.08)	(0.06)	(0.24)
Timedummy	-0.040	-0.061*	0.128
	(0.03)	(0.03)	(0.12)
Timedummy*Dumtreatment	0.127	0.105	-0.153
	(0.11)	(0.08)	(0.32)
Net liquid wealth	0.652***	0.711***	-1.326***
	(0.08)	(0.11)	(0.23)
Net liquid wealth squared	-0.115***	-0.221***	0.408***
	(0.02)	(0.05)	(0.07)
Personaldebt	1.738***	1.830***	0.616
	(0.39)	(0.48)	(1.60)
Housing	0.089*	0.149***	-0.444***
	(0.05)	(0.05)	(0.18)
Housing squared	-0.016	-0.027***	0.057***
	(0.01)	(0.01)	(0.02)
Outstanding mortgage loans	0.274***	0.260***	0.254
	(0.06)	(0.05)	(0.20)
Gross labour income	-0.058	-0.099	-0.683
	(0.14)	(0.09)	(0.44)
Incomenlw	1.03E-04***	1.62E-04	6.54E-04**
	(3.41E-05)	(1.70E-04)	(3.33E-04)
Age	0.024**	0.037***	-0.035
	(0.01)	(0.01)	(0.03)
Agesquared	-1.62E-04	-2.97E-04***	3.22E-04
	(1.10E-04)	(1.08E-04)	(3.72E-04)
Aleveldum	0.041	0.068*	-0.154
	(0.04)	(0.04)	(0.12)
Degreedum	0.071	0.116***	-0.346**
	(0.04)	(0.04)	(0.14)
Pensiondum	0.036	0.062	-0.220
	(0.04)	(0.04)	(0.14)
Sexdum	0.116***	0.082***	0.200*
	(0.03)	(0.03)	(0.11)
Maritaldum	-0.018	-0.029	0.038
	(0.04)	(0.04)	(0.12)
Childdum	0.154***	0.102***	0.298**

	(0.04)	(0.04)	(0.13)
Londondum	0.028	0.032	-0.113
	(0.05)	(0.04)	(0.16)
constant	-0.939***	-1.247***	
	(0.19)	(0.22)	
Log likelihood	-1660.2781	-1588	
No. of observations	1986	1986	
left-censored observations at α2000<=0	837	837	
uncensored observations	1005	1005	
right-censored observations at α2000>=1	144	144	

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table 4. 21:Results for Homoscedastic Tobit and Heteroscedastic Tobit regression-adjusted DD estimation, the house-owner subsample

	Homoscedastic Tobit	**Heteroscedastic Tobit**	
Variables	**coefficient**	**coefficient**	$\boxed{\gamma}$
Dumtreatment	0.053	0.113*	-0.314
	(0.08)	(0.06)	(0.26)
Timedummy	-0.027	-0.049	0.104
	(0.03)	(0.04)	(0.12)
Timedummy*Dumtreatment	0.049	0.045	-0.148
	(0.11)	(0.09)	(0.34)
Net liquid wealth	0.616***	0.658***	-1.290***
	(0.08)	(0.11)	(0.23)
Net liquid wealth squared	-0.108***	-0.195***	0.379***
	(0.02)	(0.05)	(0.07)
Personaldebt	1.634***	1.741***	0.308
	(0.39)	(0.47)	(1.62)
Housing	0.099*	0.138**	-0.313
	(0.06)	(0.06)	(0.21)
Housing squared	-0.017	-0.023***	0.031***
	(0.01)	(0.01)	(0.04)
Outstanding mortgage loans	0.283***	0.253***	0.343*
	(0.06)	(0.05)	(0.2)
Gross labour income	-0.023	-0.079	-0.672
	(0.13)	(0.09)	(0.45)
Incomenlw	7.33E-05*	1.62E-04	7.61E-04**
	(4.10E-05)	(2.05E-04)	(3.73E-04)
Age	0.024**	0.035***	-0.021
	(0.01)	(0.01)	(0.03)
Agesquared	-1.63E-04	-2.83E-04*	1.22E-04
	(1.18E-04)	(1.10E-04)	(3.49E-04)
Aleveldum	0.007	0.039	-0.193
	(0.04)	(0.04)	(0.13)
Degreedum	0.046	0.093**	-0.356**
	(0.05)	(0.04)	(0.15)
Pensiondum	0.012	0.046	-0.280*
	(0.04)	(0.04)	(0.14)
Sexdum	0.125***	0.078**	0.246**
	(0.03)	(0.03)	(0.12)
Maritaldum	-0.019	-0.036	0.058
	(0.04)	(0.04)	(0.13)
Childdum	0.121***	0.101**	0.095
	(0.04)	(0.04)	(0.13)
Londondum	0.002	0.014	-0.182
	(0.05)	(0.04)	(0.17)

constant	-0.897*** (0.21)	-1.166*** (0.22)
Log likelihood	-1473.3759	-1414
No. of observations	1770	1770
left-censored observations at α2000<=0	707	707
uncensored observations	939	939
right-censored observations at α2000>=1	124	124

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table4. 22:Results for Homoscedastic Tobit and Heteroscedastic Tobit regression-adjusted DD estimation, the non-house owner subsample

Variables	Homoscedastic Tobit coefficient	Heteroscedastic Tobit coefficient	$\boxed{\gamma}$
Dumtreatment	-0.028	-0.059	-0.108
	(0.31)	(0.32)	(3.01)
Timedummy	-0.253	0.053	0.332
	(0.16)	(0.25)	(0.64)
Timedummy*Dumtreatment	0.694*	0.579	-0.637
	(0.40)	(0.60)	(1.44)
Net liquid wealth	2.678	2.301	-14.022***
	(1.93)	(3.06)	(5.00)
Net liquid wealth squared	-2.338	-1.570	
	(3.79)	(5.32)	
Personaldebt	2.863	-27.30	8.119
	(4.12)	(23.46)	(29.76)
Outstanding mortgage loans	-0.210	-0.797	
	(1.07)	(2.47)	
Gross labour income	-2.565**	-0.190	-14.750*
	(1.30)	(0.66)	(7.60)
Incomenlw	3.29E-04	2.00E-04	
	(2.22E-04)	(1.87E-04)	
Age	0.023	0.058	0.009
	(0.03)	(0.05)	(0.05)
Agesquared	-1.43E-04	-4.47E-04	-1.92E-04
	(3.86E-04)	(3.46E-04)	(4.85E-04)
Aleveldum	0.614***	0.519**	1.005
	(0.20)	(0.23)	(0.83)
Degreedum	0.271	0.078	-0.561
	(0.24)	(0.43)	(1.19)
Pensiondum	0.428**	0.026	1.610
	(0.18)	(0.13)	(1.03)
Sexdum	0.102	0.072	1.053
	(0.15)	(0.05)	(0.80)
Maritaldum	-0.016	-0.154	0.254
	(0.16)	(0.34)	(1.37)
Childdum	0.781***	0.474	2.541*
	(0.21)	(0.75)	(1.31)
Londondum	0.442*	0.294	0.068
	(0.23)	(0.37)	(1.60)
constant	-1.301*	-2.177*	

	(0.71)	(1.32)
Log likelihood	-161.0764	-132.2632
No. of observations	216	216
left-censored observations at α2000<=0	130	130
uncensored observations	66	66
right-censored observations at α2000>=1	20	20

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table 4. 23: Earlier research results for regression-adjusted DD estimation using 1995 and 2000 of BHPS data

	Coefficients		
Variables	Model 1	Model 2	Model 3
Dumtreatment	-0.039	-0.055	-0.040
	(0.10)	(0.10)	(0.10)
Timedummy	-0.082**	-0.043	-0.077**
	(0.04)	(0.04)	(0.04)
Timedummy*Dumtreatment	0.261**	0.298**	0.263**
	(0.13)	(0.13)	(0.13)
Net liquid wealth	1.070***	1.180***	1.080***
	(0.10)	(0.10)	(0.11)
Net liquid wealth squared	-0.204***	-0.221***	-0.205***
	(0.02)	(0.02)	(0.02)
Personaldebt	2.170***	2.340***	2.190***
	(0.40)	(0.40)	(0.40)
Housing	0.305***		0.257***
	(0.05)		(0.06)
Housing squared	-0.049***		-0.041***
	(0.01)		(0.01)
Dumhousing		0.239***	0.071
		(0.05)	(0.06)
Gross labour income	0.544***	0.764***	0.559***
	(0.16)	(0.16)	(0.16)
Age	0.049***	0.0473***	0.048***
	(0.01)	(0.01)	(0.01)
Agesquared	-4.81E-04***	-4.46E-04***	-4.671E-04***
	(1.17E-04)	(1.18E-04)	(1.17E-04)
Sexdum	0.090***	0.071**	0.088***
	(0.04)	(0.04)	(0.04)
Constant	-1.719***	-1.775***	-1.738***
	(0.20)	(0.20)	(0.20)
Log likelihood	-2421.067	-2429.100	-2420.421
LR chi2	447.59	431.53	448.88
Pro>chi2	0	0	0
Pseudo R2	0.0846	0.0816	0.0849
No. of observations	3106	3106	3106
left-censored observations at α2000<=0	1870	1870	1870
uncensored observations	1029	1029	1029
right-censored observations at α2000>=1	207	207	207

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, are measured in £100,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000.

4.5.4 Short panel study on the joint impact of retirement and housing ownership

In order to examine the effect of retirement on people who owns a house compared with the effect on people who do not own a house, we will, in this section, carry out a short panel study on the joint impact of retirement and housing ownership by using the 1995 and 2000 BHPS data. We estimate regressions which include the additional dummy variables of *Dumhousingr*, *Dumhousingw* and *Dumnonhousingr*. The definitions for these three dummy variables[35] have been given in the above section 4.4.3 and the definitions for other variables are the same as in the previous chapter. The estimation results are reported in the following Table 4.24.

The difference between model one and model two is that in model one we control for an the outstanding mortgage loan whereas in model two we do not. The sign of the coefficient for each variable are the same as in both models. However, the coefficients for the dummy variables of *Dumhousingr*, *Dumhousingw* and *Dumnonhousingr* in model one and model two are not statistically significant, hence no further implication can be made from both models.

In model three of Table 4.24, we have some interesting findings. As we can see, we do not control for the housing value or outstanding mortgage loan in this model. We find that an individual who was retired during both surveys and was living in an

[35] *Dumhosuingr* equals one if in both years the individual is retired and is living in an accommodation that is owned by him/her or by his family. It equals zero if otherwise. *Dumhousingw* equals one if in both years the individual is employed and is living in an accommodation that is owned by him/her or by his family. It equals zero if otherwise. *Dumnonhousingr* equals one if in both years the individual is retired and is living in an accommodation that is not owned by him/her or by his family. It equals zero if otherwise. Dumnonhousingw equals one if in both years the individual is employed and is living in an accommodation that is not owned by him/her or by his family. It equals zero if otherwise.

accommodation that is owned by him/her or by his family holds the highest proportion of risky assets among the four categories of individuals as defined. In other words, on average, retired house owners hold the highest proportion of risky assets among all, followed by employed house owners who hold the second highest proportion of risky assets. The average risky asset shares of the other two categories of households, namely, retired non-house owners and employed non house owners are relatively the same and are the lowest among all. These results actually confirm what we found in Table 4.23 that housing ownership has a positive effect. This is because housing can be considered to provide financial security which may reduce the individuals' relative risk aversion and encourage them to invest a higher proportion of wealth in risky assets. Therefore, compared with individuals living in not self or family-owned accommodation (non-house-owners), individuals who do live in those accommodations (house-owners) will generally take a higher risky position in investment.

In model three of Table 4.24, the retirement status seems to have different effects on risky asset allocations for house owners and non-house owners. The coefficients for *Dumhousingr* and *Dumhousingw* are 0.218 and 0.101 respectively, which are both statistically significant. This could reveal that for house owners, due to retirement they receive annuity and pension payment which are normally less correlated with the economic condition, and this retirement status will have a positive impact on risky asset holdings. While for non-house owners, the retirement status may have a negative impact as the coefficient for *Dumnonhousingr* is -0.062 in Table 4.24, although this effect is not statistically significant. The explanation could be that retired non house-owners are more risk averse than employed non-house owners. When a non-house owner has a job, he/she tends to be the low income household and his/her consumption level is close to habit level. Because the retirement would reduce his/her annual income and bring his/her consumption even closer to habit level, the retired non-house owner would be more risk averse. Therefore, in comparison, the retired non-house owners are less willing to take a risky position in investment than employed non-house owners. However, since this retirement effect for non-house owners is not statistically significant, we need to interpret the above explanation with caution.

Model four is used for comparison reason. The dummy variables of *Dumhousingr*, *Dumhousingw* and *Dumnonhousingr* are not included in Model four. As we can see, gross house value has an inverse-U shape of impact on risky asset share.

From model 1 to model 4, we set up these models by pooling the 1995 and 2000 BHPS data together and run the standard tobit regression. In comparison, we set up model 5 which is a random effect Tobit model. In terms of sign and significance level, the results in model 5 are same as in model 2, which suggests that our previous findings in model 2 are robust. We also report the marginal effects after random effect Tobit model. The marginal effects measure the expected change in risky asset share as a function of one unit increase in the explanatory variable. The sixth column presents the value of dy/dx and the seventh column presents the average value of the explanatory variable. As we can see, if average net liquid wealth increases by £100,000, the expected/predicted risky asset share would increase by 27.2 percentage point. An increase of £100,000 in personal debt would result in an increase of 94 percentage point in expected risky asset share. Compared with employed non-house owners, retired house owners invest 11.4 percentage point higher and employed house owners invest 5.7 percentage point higher. The marginal effect of *incomenlw* on risky asset share is close to zero but is positive and significant. An increase of 10 years in average age would increase the expected risky asset share by 11.88 percentage point. Because the marginal effect of the dummy variables is measured in terms of discrete change of dummy variable from 0 to 1, the results in Table 4.24 suggest that an individual whose highest education level is first degree or higher would invest 5.6 percentage point higher than an individual with whose highest education is an O-level or under. Compared with average female's risky asset share, the risky asset share of male is 3.4 percentage point higher. The presence of chid/children increases the risky asset share by 7.3 percentage point.

Table 4. 24: Results for short panel study on the joint impact of retirement and housing ownership

	Coefficients					Marginal effects after xttobit	
Variables	Model 1	Model 2	Model 3	Model 4	Model 5 (xttobit)	dy/dx	X
Net liquid wealth	0.673***	0.649***	0.730***	0.704***	0.670***	0.334***	0.133
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.03)	
Net liquid wealth squared	-0.118***	-0.117***	-0.133***	-0.124***	-0.124***	-0.062***	0.135
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	
Personaldebt	1.816***	1.963***	2.144***	1.869***	1.885***	0.940***	0.012
	(0.38)	(0.38)	(0.38)	(0.38)	(0.37)	(0.18)	
Dumhousingr	0.065	0.099	0.218***		0.219**	0.114**	0.225
	(0.08)	(0.08)	(0.08)		(0.09)	(0.05)	
Dumhousingw	-0.057	-0.035	0.101*		0.116*	0.057*	0.628
	(0.06)	(0.06)	(0.06)		(0.06)	(0.03)	
Dumnonhousingr	-0.102	-0.041	-0.062		-0.066	-0.032	0.073
	(0.09)	(0.09)	(0.09)		(0.10)	(0.05)	
Housing	0.159***	0.202***		0.188***			
	(0.05)	(0.05)		(0.04)			
Housing squared	-0.025**	-0.030***		-0.030***			
	(0.01)	(0.01)		(0.01)			
Outstanding mortgage loans	0.190***			0.174***			
	(0.05)			(0.05)			
Gross labour income	-0.034	0.073	0.190	-0.100	0.113	0.057	0.127
	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.06)	
Incomenlw	9.20E-05***	8.98E-05***	8.54E-05**	9.35E-05***	9.01E-05***	4.49E-05***	32.218
	(3.41E-05)	(3.40E-05)	(3.39E-05)	(3.39E-05)	(3.46E-05)	(2.00E-05)	
Age	0.026***	0.023***	0.025***	0.025***	0.026***	0.013***	49.995
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(2.89E-03)	

Agesquared	-2.24E-04***	-2.08E-04***	-2.15E-04***	-2.07E-04***	-2.24E-04***	-1.12E-04***	2814.220
	(5.21E-05)	(5.21E-05)	(5.24E-05)	(4.89E-05)	(5.78E-05)	(3.00E-05)	
Aleveldum	0.038	0.038	0.046	0.036	0.048	0.024	0.273
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)	
Degreedum	0.053	0.063	0.088**	0.055	0.109**	0.056**	0.131
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.03)	
Pensiondum	0.037	0.046	0.037	0.017	0.035	0.017	0.526
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)	
Sexdum	0.079***	0.067**	0.057**	0.084***	0.068**	0.034**	0.502
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	
Maritaldum	0.021	0.028	0.044	0.023	0.053	0.026	0.652
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	
Childdum	0.139***	0.152***	0.161***	0.134***	0.142***	0.073***	0.209
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)	
Londondum	0.002	0.003	0.034	-0.010	0.032	0.016	0.103
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.02)	
constant	-0.910***	-0.837***	-0.922***	-0.939***	-0.951***		
	(0.14)	(0.14)	(0.14)	(0.13)	(0.15)		
Log likelihood	-2128.953	-2135.946	-2146.950	-2134.283	-2077.223		
LR chi2	411.14	397.15	375.14	400.47	284.71		
Pro>chi2	0	0	0	0	0		
Pseudo R2	0.0881	0.0851	0.0803	0.0858			
No. of observations	2584	2584	2584	2584	2584		
left-censored observations at α2000<=0	1099	1099	1099	1099	1099		
uncensored observations	1302	1302	1302	1302	1302		
right-censored observations at α2000>=1	183	183	183	183	183		

Note:

*,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

4.6 Conclusion

In conclusion, this chapter has investigated how the portfolios of the UK households evolve leading up to retirement and beyond. In particular, we examined the impact of retirement, housing value and ownership on the households' risky portfolio by using data from the British Household Panel Survey (BHPS).

We first used individual level data from the BHPS for years 1995 and 2000 respectively and carried out cross-sectional studies. For each year, we divided the sample into two subsamples, namely house-owner subsample and non-house owner subsample. As we did in the previous chapter, the standard Tobit model has been estimated, followed by the hetroskedastic Tobit model. We found that in 1995 for the house owner if the individual opted for early retirement, then his/her average risky asset share will increase by 21 percentage points and this effect is significantly different from zero at the 5% level. However, under the hetroskedastic Tobit model, this positive effect disappeared in 1995. In contrast, in 2000, for the house owner if he/she opt for early retirement, then his/her average risky asset share will increase by approximately 12 percentage in point, which is statistically significant under the standard Tobit and hetroskedastic Tobit model. In addition, for house owners again, the normal retirement has also been found to have a positive impact on risky asset shares. Although this effect is statistically insignificant in a standard Tobit model , it becomes statistically significant in hetroskedastic Tobit regression. However, for the non-house owner subsample, both in 1995 and 2000, all else equal, we have not found the retirement effect in both models.

In the cross-sectional studies, we also notice that for the non-house owner subsample, a pension has a very significant positive impact on an individual's risky asset allocations. In 2000, Participating in private and/or public pension schemes will increase the individual's average risky asset share by 11.4 percentage point for the house-owners and increase by 25.4 percentage point for the non-house owners. After controlling for the heteroscedastic problem, the pension effect is increased to 14.7 percentage point for the house-owners and is increased dramatically to 52.3 percentage point for the non-house owners. All these impacts are statistically significant from zero. In comparison, in 1995, for the non-house owners the coefficient of *Pensiondum* is 0.21 in the standard homosedastc Tobit model and it is statistically significant. Again, this pension effect is not that huge for the house-owner subsample. The coefficient of *Pensiondum* is 0.075 and it equals 0.104 after controlling for the heteroscedastic problem. Both coefficients are statistically significant.

Later we set up a dummy variable for house owners and interact this dummy variable with other explanatory variables by using the full sample, so that we are able to examine the effects of each repressor on the risky asset holdings of house owners and non-house owners respectively. This can be regarded as providing robustness test for our previous results. We find that, in both years, for non-house owners, after controlling for other social and economic factors, neither early retirement nor normal retirement has an impact on portfolio share of risky assets. However, early retirement has positive impact on risky asset holdings for house owners. We then carry out robustness tests and the results are confirmed. We also find that compared with non-house owners, the early retirement increase the proportion of net wealth invested in risky assets by 30.3 percentage point for house owners in 1995.

We then focus on a specific group of households who are either approaching their retirement age or at the early stage of their retirement. By adopting regression-adjusted DD estimation methods, as we can see from Table 4.23, we found that if we control for net liquid wealth, personal debt, housing, gross labour income, age and gender only, the changes in labour force participation status or the event of retirement has a positive impact on households' risky portfolio and this impact is significantly different from zero at the 5 percentage level.

This implies that the households who have just entered their retirement stage or who are in the early stage of their retirement would increase risk exposure of their total investment portfolio by allocating a higher proportion of their wealth to the risky assets. This finding is consistent with some of the existing literature which suggest that there is an inversed-U shape of age effect on the elderly' risky portfolio, for example, the findings in Ameriks and Zeldes (2004), Wachter and Yogo (2010), and Guiso *et al.* (2002). Guiso *et al.* (2002, pp11) reported that in the UK, Germany and Italy, there is "a hump-shaped age profile of participation in risky assets". The households in those three countries have the highest probability of holding risky assets when they are in the age of 50s. The explanation could be that in the early stage of their retirement, although they faces a significantdrop in the labour income, they receive streams of income from their pensions which can be regarded or treated as risk-free assets in their entire portfolio. In comparison, before they retire, their labour income is considered to be positively correlated with the economic condition. To some extent, the income risk involved in this positive relationship would discourage householder to put a heavy weight on the risky assets investment. While at the early stage of their retirement, they still have a relatively long investment horizon, their income from a pension is continuous and risk-free, they may still have a strong desire to accumulate their wealth and plan to spend it at a later life in terms of health consumption and maintaining their standard of life or make bequest to their next generation. Furthermore, during the early stage of their retirement, they may still have the desire to work and to be connected with the society, and importantly, their health are normally in good condition and they have a lot of time that could be spent on managing their investment portfolio. Therefore, it is rational for the elderly who have a good financial capability to take a little bit more risk and invest a higher proportion of wealth in risky assets.

One problem is that if we control for all the socioeconomic and demographic variables (ie: except the previous control variable, we have additional control variable of outstanding mortgage loans, the ratio of income to net liquid wealth, dummy variable for education level, pension, marital status, children, region), then no effect of retirement is found, as can be seen from Table 4.19-4.22.

Lastly, in this chapter, we do a short panel study on the joint impact of retirement and housing ownership and found that an individual who was retired during both surveys and was living in an accommodation that is owned by him/her or by his family holds the highest proportion of risky assets among the four categories of individuals as defined. The employed house owners hold the second highest proportion of risky assets. The average risky asset shares of the other two categories of households, namely, retired non-house owners and employed non-house owners are relatively the same and are the lowest among all. These results are statistically significant. We also find that compared with employed non-house owners, retired house owners invest 11.4 percentage point higher and employed house owners invest 5.7 percentage point higher.

These imply that, compared with labour income, the ownership of a house could provide a stronger financial security for the households to take risk in their investment. For the elderly, they will be more willing to take risk if they own a house. They can take a reverse-mortgage their house at their later life to finance their daily consumption, after they spend their savings which are relatively easy to access due to the liquidity preference.

Appendix:

Table (A):

Variable	Treatment group Mean	[	Std. Dev.	]	Control group Mean	[	Std. Dev.	]
allocation1995	0.36	[	0.37	]	0.28	[	0.37	]
allocation2000	0.41	[	0.38	]	0.31	[	0.37	]
netliquidwealth1995	36.21	[	77.87	]	7.94	[	30.00	]
netliquidwealth2000	35.97	[	69.25	]	10.18	[	29.59	]
personaldebt1995	0.55	[	1.12	]	1.19	[	2.44	]
personaldebt2000	0.08	[	0.34	]	2.03	[	5.24	]
housing1995	68.61	[	49.01	]	64.81	[	45.45	]
housing2000	112.99	[	98.53	]	108.21	[	91.70	]
outstandingmortgage1995	6.88	[	14.98	]	31.30	[	31.67	]
outstandingmortgage2000	3.55	[	11.51	]	34.69	[	38.77	]
grossincome1995	14.35	[	11.67	]	16.13	[	12.56	]
grossincome2000	0.22	[	1.40	]	19.87	[	15.09	]
incomenlw1995	83.22	[	678.59	]	30.58	[	280.59	]
incomenlw2000	-0.01	[	0.74	]	61.19	[	653.00	]
age1995	57.90	[	6.04	]	37.84	[	10.42	]
age2000	63.06	[	6.02	]	43.02	[	10.41	]
olevelorunderdum1995	0.80	[	0.40	]	0.51	[	0.50	]
olevelorunderdum2000	0.80	[	0.40	]	0.48	[	0.50	]
aleveldum1995	0.10	[	0.31	]	0.33	[	0.47	]
aleveldum2000	0.10	[	0.31	]	0.34	[	0.47	]
degreedum1995	0.09	[	0.29	]	0.16	[	0.37	]
degreedum2000	0.09	[	0.29	]	0.18	[	0.39	]
pensiondum1995	0.60	[	0.49	]	0.72	[	0.45	]
pensiondum2000	0	[	0	]	0.77	[	0.42	]
employeedum1995	1	[	0	]	1	[	0	]
employeedum2000	0	[	0	]	1	[	0	]
selfemployeddum1995	0	[	0	]	0	[	0	]
selfemployeddum2000	0	[	0	]	0	[	0	]
retireddum1995	0	[	0	]	0	[	0	]
retireddum2000	1	[	0	]	0	[	0	]
unemployeddum1995	0	[	0	]	0	[	0	]
unemployeddum2000	0	[	0	]	0	[	0	]
sexdum1995	0.53	[	0.50	]	0.51	[	0.50	]
sexdum2000	0.53	[	0.50	]	0.51	[	0.50	]

maritaldum1995	0.72	[0.45]	0.66	[0.47]
maritaldum2000	0.71	[0.46]	0.68	[0.46]
childdum1995	0.02	[0.15]	0.30	[0.46]
childdum2000	0.02	[0.15]	0.29	[0.46]
londondum1995	0.08	[0.28]	0.11	[0.31]
londondum2000	0.06	[0.24]	0.10	[0.31]
No. of observations	86		907	

Note: standard errors are in square brackets.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table (B):

	Treatment group		Control group	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.39	[0.37]	0.28	[0.37]
allocation2000	0.41	[0.37]	0.32	[0.37]
netliquidwealth1995	41.17	[83.42]	8.45	[31.52]
netliquidwealth2000	41.26	[73.95]	10.80	[30.91]
personaldebt1995	0.65	[1.19]	1.26	[2.52]
personaldebt2000	0.09	[0.37]	2.11	[5.41]
housing1995	80.83	[42.83]	72.39	[41.94]
housing2000	133.11	[93.51]	120.87	[88.67]
outstandingmortgage1995	8.10	[15.97]	34.90	[31.51]
outstandingmortgage2000	3.74	[11.96]	38.62	[39.06]
grossincome1995	15.73	[12.05]	16.79	[12.89]
grossincome2000	0.26	[1.52]	20.78	[15.47]
incomenlw1995	85.79	[730.89]	29.67	[277.52]
incomenlw2000	-0.02	[0.81]	43.73	[435.74]
age1995	57.37	[6.21]	37.88	[10.05]
age2000	62.52	[6.18]	43.05	[10.04]
olevelorunderdum1995	0.79	[0.41]	0.49	[0.50]
olevelorunderdum2000	0.79	[0.41]	0.46	[0.50]
aleveldum1995	0.10	[0.30]	0.34	[0.47]
aleveldum2000	0.10	[0.30]	0.35	[0.48]
degreedum1995	0.11	[0.31]	0.17	[0.37]
degreedum2000	0.11	[0.31]	0.19	[0.39]

pensiondum1995	0.64	[0.48]	0.75	[0.43]
pensiondum2000	0	[0]	0.79	[0.41]
employeedum1995	1	[0]	1	[0]
employeedum2000	0	[0]	1	[0]
selfemployeddum1995	0	[0]	0	[0]
selfemployeddum2000	0	[0]	0	[0]
retireddum1995	0	[0]	0	[0]
retireddum2000	1	[0]	0	[0]
unemployeddum1995	0	[0]	0	[0]
unemployeddum2000	0	[0]	0	[0]
sexdum1995	0.56	[0.50]	0.52	[0.50]
sexdum2000	0.56	[0.50]	0.52	[0.50]
maritaldum1995	0.75	[0.43]	0.69	[0.46]
maritaldum2000	0.74	[0.44]	0.72	[0.45]
childdum1995	0.03	[0.16]	0.31	[0.46]
childdum2000	0.01	[0.12]	0.31	[0.46]
londondum1995	0.10	[0.30]	0.11	[0.31]
londondum2000	0.07	[0.25]	0.10	[0.30]
No. of observations	73		812	

Note: standard errors are in square brackets.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table (C):

	Treatment group		**Control group**	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.19	[0.31]	0.22	[0.37]
allocation2000	0.41	[0.43]	0.20	[0.35]
netliquidwealth1995	8.34	[14.37]	3.57	[8.85]
netliquidwealth2000	6.25	[5.58]	4.88	[12.64]
personaldebt1995	0.02	[0.06]	0.61	[1.42]
personaldebt2000	0	[0]	1.39	[3.38]
housing1995	0	[0]	0	[0]
housing2000	0	[0]	0	[0]
outstandingmortgage1995	0	[0]	0.57	[5.54]
outstandingmortgage2000	2.46	[8.88]	1.09	[7.12]

grossincome1995	6.59	[4.01]	10.50	[7.15]
grossincome2000	0.00	[0.00]	12.10	[7.87]
incomenlw1995	68.79	[237.14]	38.37	[307.09]
incomenlw2000	0.00	[0.00]	210.45	[1564.17]
age1995	60.85	[3.93]	37.45	[13.21]
age2000	66.08	[3.93]	42.73	[13.17]
olevelorunderdum1995	0.85	[0.38]	0.71	[0.46]
olevelorunderdum2000	0.85	[0.38]	0.67	[0.47]
aleveldum1995	0.15	[0.38]	0.19	[0.39]
aleveldum2000	0.15	[0.38]	0.21	[0.41]
degreedum1995	0	[0]	0.11	[0.31]
degreedum2000	0	[0]	0.12	[0.32]
pensiondum1995	0.38	[0.51]	0.49	[0.50]
pensiondum2000	0	[0]	0.61	[0.49]
employeedum1995	1	[0]	1	[0]
employeedum2000	0	[0]	1	[0]
selfemployeddum1995	0	[0]	0	[0]
selfemployeddum2000	0	[0]	0	[0]
retireddum1995	0	[0]	0	[0]
retireddum2000	1	[0]	0	[0]
unemployeddum1995	0	[0]	0	[0]
unemployeddum2000	0	[0]	0	[0]
sexdum1995	0.38	[0.51]	0.39	[0.49]
sexdum2000	0.38	[0.51]	0.39	[0.49]
maritaldum1995	0.54	[0.52]	0.38	[0.49]
maritaldum2000	0.54	[0.52]	0.35	[0.48]
childdum1995	0.00	[0.00]	0.21	[0.41]
childdum2000	0.08	[0.28]	0.17	[0.38]
londondum1995	0	[0]	0.13	[0.33]
londondum2000	0	[0]	0.12	[0.32]
No. of observations	13		95	

Note: standard errors are in square brackets.

Netliquidwealth, Personaldebt, Housing, Outstandingmortgage are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table (D): models with interaction terms and marginal effect for 2000

Varibles	Model 1	Model 2	marginal effect for model 2	
			dy/dx	X
Dumearlyretirement	0.214	0.197	0.088	0.041
	(0.20)	(0.20)	(0.10)	
Dumnormalretirement	0.193	0.180	0.078	0.267
	(0.13)	(0.13)	(0.06)	
Netliquidwealth	1.612***	1.592***	0.659***	0.104
	(0.25)	(0.25)	(0.10)	
Netliquidwealthsquared	-0.353***	-0.347***	-0.144***	0.107
	(0.08)	(0.08)	(0.03)	
Personaldebt	1.975**	2.147**	0.889**	0.016
	(1.00)	(1.01)	(0.42)	
Housing	0.170***	0.168***	0.069***	0.786
	(0.04)	(0.04)	(0.01)	
Housingsquared	-0.027***	-0.027***	-0.011***	1.219
	(0.01)	(0.01)	(3.08E-03)	
Outstandingmortgage	0.359	0.343	0.142	0.220
	(0.28)	(0.29)	(0.12)	
Grosslabourincome	0.135	0.050	0.021	0.121
	(0.52)	(0.53)	(0.22)	
Incomenlw	1.97E-06	9.32E-06	3.86E-06	78.515
	(2.17E-05)	(2.20E-05)	(1.00E-05)	
Age	0.023***	0.027***	0.011***	48.775
	(0.01)	(0.01)	(2.34E-03)	
Agesquared	-2.22E-04***	-2.54E-04***	-1.05E-04***	2730.680
	(6.10E-05)	(6.33E-05)	(3.00E-05)	
Aleveldum	0.219***	0.210***	0.091***	0.260
	(0.07)	(0.07)	(0.03)	
Degreedum	0.111	0.094	0.040	0.148
	(0.09)	(0.09)	(0.04)	
Pensiondum	0.170**	0.162**	0.067**	0.455
	(0.07)	(0.07)	(0.03)	
Sexdum	0.098*	0.083	0.034	0.480
	(0.05)	(0.06)	(0.02)	
Maritaldum	-0.007	0.001	3.00E-04	0.563
	(0.06)	(0.06)	(0.02)	
Childdum	0.097	0.306***	0.137**	0.193

	(0.08)	(0.12)	(0.06)	
Numberofkids		-0.129**	-0.053**	0.451
		(0.05)	(0.02)	
Londondum	0.165*	0.153*	0.067	0.063
	(0.09)	(0.09)	(0.04)	
Healthstatus		-0.047	-0.019	2.148
		(0.03)	(0.01)	
Dumearlyretirementdumhousing	0.082**	0.063*	0.025*	0.036
	(0.04)	(0.04)	(0.02)	
Dumnorretirementdumhousing	-0.110	-0.098	-0.039	0.182
	(0.14)	(0.14)	(0.05)	
Netliquidwealthdumhousing	-0.660**	-0.649**	-0.269**	0.095
	(0.26)	(0.26)	(0.11)	
Nlwsquareddumhousing	0.144*	0.140*	0.058*	0.100
	(0.08)	(0.08)	(0.03)	
Personaldebtdumhousing	-0.297	-0.472	-0.196	0.013
	(1.03)	(1.03)	(0.43)	
Outstandingmdumhousing	-0.275	-0.257	-0.106	0.217
	(0.29)	(0.29)	(0.12)	
Grosslabourincomedumhousing	-0.070	0.005	0.002	0.103
	(0.54)	(0.54)	(0.23)	
Incomenlwdumhousing	-7.02E-05	-7.76E-05*	-3.22E-05*	45.695
	(4.65E-05)	(4.67E-05)	(2.00E-05)	
Agedumhousing	0.006	0.002	0.001	37.320
	(4.22E-03)	(0.01)	(2.07E-03)	
Agesquareddumhousing	-9.75E-06	2.75E-05	1.14E-05	2039.250
	(5.95E-05)	(6.40E-05)	(3.00E-05)	
Aleveldumdumhousing	-0.185**	-0.179**	-0.070**	0.221
	(0.08)	(0.08)	(0.03)	
Degreedumdumhousing	-0.069	-0.056	-0.023	0.124
	(0.10)	(0.10)	(0.04)	
Pensiondumdumhousing	-0.049	-0.044	-0.018	0.392
	(0.08)	(0.08)	(0.03)	
Sexdumdumhousing	-0.034	-0.021	-0.008	0.381
	(0.06)	(0.06)	(0.03)	
Maritaldumdumhousing	0.019	0.012	0.005	0.489
	(0.07)	(0.07)	(0.03)	
Childdumdumhousing	-0.044	-0.198	-0.077*	0.161
	(0.09)	(0.13)	(0.05)	
Numberofkidsdumhousing		0.093	0.039	0.358
		(0.06)	(0.02)	
Londondumdumhousing	-0.171	-0.159	-0.061*	0.042
	(0.10)	(0.10)	(0.04)	

Healthstatusdumhousing		0.023	0.010	1.625
		(0.03)	(0.01)	
Constant	-1.164***	-1.090***		
	(0.11)	(0.11)		
Log likelihood	-4053.46	-4046.65		
LR chi2	840.98	854.59		
Pro>chi2	0	0		
Pseudo R2	0.094	0.0955		
No. of observations	4927	4927		
left-censored observations at α2000<=0	2505	2505		
uncensored observations	2036	2036		
right-censored observations at α2000>=1	386	386		

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage and Grosslabourincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table (E): Table (D) continued

Varibles	**Model 3** regress on ***pincome, pincomenlw***	**Model 4** compared with model 3	**Model 5** probit
Dumearlyretirement	0.137	0.107	0.235
	(0.20)	(0.21)	(0.33)
Dumnormalretirement	0.286	0.282	0.328
	(0.18)	(0.18)	(0.20)
Netliquidwealth	3.222***	3.290***	2.947***
	(0.72)	(0.72)	(0.50)
Netliquidwealthsquared	-2.894***	-2.968***	-0.621***
	(1.05)	(1.05)	(0.18)
Personaldebt	4.443***	4.674***	2.524
	(1.33)	(1.35)	(1.70)
Housing	0.124***	0.135***	0.467***
	(0.04)	(0.04)	(0.08)
Housingsquared	-0.022***	-0.024***	-0.068***
	(0.01)	(0.01)	(0.02)
Outstandingmortgage	0.243	0.291	0.887
	(0.28)	(0.28)	(0.54)
Grosslabourincome		-0.396	0.619
		(0.57)	(0.85)

Incomenlw		1.50E-05	-3.40E-07
		(2.19E-05)	(3.79E-05)
Permanentincome	0.427		
	(0.83)		
Permanetincomenlw	1.81E-05		
	(3.81E-05)		
Age	0.023*	0.030**	0.047***
	(0.01)	(0.01)	(0.01)
Agesquared	-2.14E-04	-2.98E-04*	-4.22E-04***
	(1.69E-04)	(1.62E-04)	(1.03E-04)
Aleveldum	0.238**	0.272***	0.419***
	(0.09)	(0.08)	(0.12)
Degreedum	0.041	0.102	0.221
	(0.13)	(0.10)	(0.16)
Pensiondum	0.104	0.124	0.252**
	(0.07)	(0.08)	(0.12)
Sexdum	0.137**	0.158**	0.080
	(0.07)	(0.07)	(0.09)
Maritaldum	-0.004	-0.006	0.006
	(0.08)	(0.08)	(0.10)
Childdum	0.234*	0.239*	0.262
	(0.13)	(0.13)	(0.19)
Numberofkids	-0.129**	-0.133**	-0.151*
	(0.06)	(0.06)	(0.08)
Londondum	0.200*	0.225**	0.183
	(0.10)	(0.11)	(0.14)
Healthstatus	-0.047	-0.046	-0.097**
	(0.04)	(0.04)	(0.05)
Dumearlyretirementdumhousing	0.021*	0.012*	0.191*
	(0.01)	(0.01)	(0.10)
Dumnorretirementdumhousing	-0.162	-0.144	-0.213
	(0.19)	(0.19)	(0.23)
Netliquidwealthdumhousing	-2.202***	-2.262***	1.031*
	(0.72)	(0.72)	(0.55)
Nlwsquareddumhousing	2.672**	2.745***	-0.137
	(1.05)	(1.05)	(0.19)
Personaldebtdumhousing	-2.709**	-2.941**	2.626
	(1.36)	(1.37)	(1.83)
Outstandingmdumhousing	-0.140	-0.178	-0.934*
	(0.29)	(0.29)	(0.55)
Grosslabourincomedumhousing		0.400	-0.188
		(0.59)	(0.90)
Incomenlwdumhousing		-6.78E-05	-9.43E-05
		(4.24E-05)	(7.71E-05)

Permanentincomedumhousing	0.322		
	(0.89)		
Permanetincomenlwdumhousing	-6.14E-05		
	(5.24E-05)		
Agedumhousing	0.003	0.003	0.002
	(0.01)	(0.01)	(0.01)
Agesquareddumhousing	1.68E-05	1.73E-05	2.87E-05
	(1.33E-04)	(1.25E-04)	(1.07E-04)
Aleveldumdumhousing	-0.264***	-0.256***	-0.291**
	(0.10)	(0.09)	(0.13)
Degreedumdumhousing	-0.093	-0.069	-0.007
	(0.14)	(0.11)	(0.17)
Pensiondumdumhousing	-2.94E-04	-0.014	-0.081
	(0.08)	(0.08)	(0.14)
Sexdumdumhousing	-0.054	-0.063	-0.027
	(0.07)	(0.08)	(0.10)
Maritaldumdumhousing	0.016	0.016	0.097
	(0.09)	(0.09)	(0.11)
Childdumdumhousing	-0.156	-0.160	-0.131
	(0.14)	(0.14)	(0.21)
Numberofkidsdumhousing	0.105*	0.108*	0.078
	(0.06)	(0.06)	(0.10)
Londondumdumhousing	-0.207*	-0.236*	-0.186
	(0.12)	(0.12)	(0.18)
Healthstatusdumhousing	0.036	0.034	-0.001
	(0.04)	(0.04)	(0.05)
Constant	-1.087***	-1.148***	-1.996***
	(0.20)	(0.20)	(0.18)
Log likelihood	-2973.19	-2974.14	-2718.28
LR chi2	610.82	608.91	1392.31
Pro>chi2	0	0	0
Pseudo R2	0.0932	0.0929	0.2039
No. of observations	3599	3599	4927
left-censored observations at α2000<=0	1782	1782	
uncensored observations	1544	1544	
right-censored observations at α2000>=1	273	273	

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage,Grosslabourincome, and Permanentincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

5:The Impact of Taxation on the Household Risky Asset Choice

5.1 Introduction

The impact of taxation on household portfolio allocation has long been an important issue which attracts attention from academics and policymakers (Alan *et al*, 2010, p1). The tax rates in the UK changed considerably during 1999 and 2001. In the tax year 1999-2000, the lower rate of personal income tax was reduced from 23% to 10% while the basic rate and higher rate remained the same at 23% and 40% respectively. In the tax year 2000-2001, the basic rate of personal income tax fell slightly from 23% to 22% whereas the lower rate of capital gain tax was reduced from 20% to 10%. Although this cut in personal income tax and capital gain tax was dramatic, the effects of this taxation reform in the UK on household portfolio choice have not been widely studied. In comparison, several papers studied the US household portfolio structure and examined the effect of taxation on portfolio allocation using household level datasets including Feldstein (1976), King and Leape (1998), Hubbard (1985), Scholz (1994), Samwick (2000) and Poterba and Samwick (2002). Partly due to the limitation of "reliable information on the asset holdings of the high-wealth households who hold a significant share of financial assets" (Poterba and Samwick, 2003, p6), limited work has been implemented on this topic in other countries. The exceptions are Agell and Edin (1990) on marginal taxation and asset portfolios in Sweden, Hochguertel *et al* (1997) on households' portfolio choices in the Netherlands, Alan *et al.* (2010) on Canadian's taxation and portfolio allocation, and Stephens and Ward-Batts's (2004) research which explores the effect of separate taxation on the intra-household portfolio allocation in the UK.

This chapter will examine the impact of this tax reforms on portfolio shares in risky assets. The specific issue on which we focus is the effect of the tax change on the proportion of risky assets which individual investors hold. In this context we are asking the extent to which tax changes affect households' optimal portfolio risk. Clearly there are two opposing forces. A tax change will have both substitution and wealth effects. The substitution effect is defined as the effect of a tax change on risky asset holding arising from the individual switching to or from risk-free asset holding. The wealth effect is defined as the effect of a tax change on risky asset holding arising from the individual becoming better or worse off due to the tax change. If the substitution effect dominates we expect to see the fall in tax would lead to higher risky assets holdings. If the wealth effect dominates then households would move to safer assets. The substitution effect is defined as the effect of a tax change on risky asset holding arising from the individual switching to or from risk-free asset holding. The wealth effect is defined as the effect of a tax change on risky asset holding arising from the individual becoming better or worse off due to the tax change.

The main empirical technique applied in this chapter is the Difference-in-Difference estimator. We will examine the effect of changes in tax (tax allowance and tax rate) using the British Household Panel Survey (BHPS) since we have substantial information on the risky and the risk-free asset holdings of the respondents and we can identify the tax bracket which should apply to each respondent. Furthermore, we will model portfolio selection controlling for taxation, which will give some insights into the effect of tax rates on asset choice. The policy implications of this analysis will also be highlighted.

The remainder of this chapter is organised as follows. The next section 5.2 presents a brief review of the related literature on the topic of taxation and portfolio choice. Section 5.3 looks at Tax reform in the UK during 1999 and 2001. In section 5.4 we discuss the impact of taxation on an individual's asset allocation from a theoretical perspective. Section 5.5 provides further details on our BHPS dataset and research methods, and Section 5.6 reports our results. The conclusion is finally drawn in Section 5.7.

5.2 Literature Review

As mentioned before, several papers studied the US household portfolio structure and examined the effect of taxation on the portfolio allocation using the household level datasets. For example, Feldstein (1976), King and Leape (1998), Hubbard (1985), Poterba and Samwick (2003) used different methods to simulate and calculate the marginal tax rate, and they found taxation to have a "strong effect" on household asset allocations (Alan *et al*., 2010, p813). Other researchers, such as Scholz (1994) and Samwick (2000), adopted Difference-in-Differences method to study how changes in tax have an impact on asset allocation.

Feldstein (1976) provided "the first systematic econometric analysis of taxation and portfolio choice" (Poterba, 2002b, p1127). He used household level data from the 1962 Survey of Financial Characteristics of Consumers. In his model, there were seven asset classes including common stock, preferred stock, bonds, municipal bonds, savings bonds, bank accounts and interest in trust. To overcome a potential endogeneity problem, instead of actual income, adjusted income was used. The adjusted income equals actual income plus five percent multiplied by the individual's financial portfolio wealth. Based on the value of adjusted income, an individual's tax class and marginal tax rate was determined and calculated. Feldstein (1976, p631) found that "the personal income tax has a very powerful effect on individual's demands for portfolio assets after adjusting for the effects of net worth, age, sex and the ratio of human to nonhuman capital". Individuals with a higher marginal tax rate invested a higher proportion of wealth in common stocks and a lower proportion of wealth in bank accounts. Furthermore, Feldstein (1976) also pointed out that this positive relationship between marginal tax rate and risky asset share should be interpreted in the way that it was the tax structure which "encourages individuals with high tax rates to hold common stocks" (Feldstein, 1976, p641), since the highest rate for capital gain was 25 percentage in the US in 1962, compared with a maximum marginal income tax rate of 91%.

Later King and Leape (1998) carried out research on the impact of marginal tax rates on portfolio allocation of US households. They use a special high-net-wealth survey which was conducted in 1978 by the Stanford Research Institute (SRI) and had a sample of 6010 households. The way in which they calculated the marginal tax rate for each household is more reliable than other methods used in previous studies, since they used a program named TAXSIM which was developed by the National Bureau of Economics Research (NBER) and it "generated tax liabilities for each household using both the federal and state tax code relevant for the appropriate tax year[36]" (King and Leape, 1998, p160-p161). In their model, a households' portfolio was defined as households' net worth which consists of all kinds of assets, mortgages and debts, such as checking accounts, less liquid savings, contractual liquid savings, corporate equity, taxable bonds, municipal bonds, owner-occupied housing, other assets, home mortgages and other liabilities. In order to deal with the problem that "most households owned incomplete portfolios" (King and Leape, 1998, p161), they adopted a two-stage estimation methods. They first estimated probit model for ownership of each assets as well as mortgage and other debts, then they estimated an asset demand equation for each assets, mortgage and other debts. The main finding of their empirical study was that taxation had significant impact on the ownership for different categories of assets, mortgage and debts, whereas conditional on the ownership, it had limited impact on the proportion of investment in different classes of assets, mortgage and debts.

Hubbard's (1985, p57) work provided strong support for the conclusion drawn in Feldstein's (1976) empirical study that "under the special features of the U.S. tax system, higher marginal tax rates increase the demand for equities". The dataset he used in the research was uniquely collected by the US President's Commission on Pension Policy in 1979 and 1980. He first estimated probit models to examine the effect of marginal tax rates on the discrete portfolio choice of individuals, followed by estimating

[36] Feenberg (1982), and Feenberg and Rosen (1983) provided much detailed information on TAXSIM program.

asset demand equations to examine the effect of marginal tax rates on the continuous portfolio choice. In both estimation stages, marginal tax rates were estimated by using the NBER TAXSIM programme and the following assets were analyzed, namely, "market value of the home, U.S. savings bonds, deposits, annuities, bonds, equity, and passenger cars" (Hubbard, 1985, p56). Furthermore, total debts, including mortgage and consumer debts, were also considered as a part of individual's portfolio and it was analysed in the way as other assets. After controlling for "present value of anticipated social security and private pension benefits" and other demographic and economic factors, Hubbard concluded that "marginal tax rates are quite important for asset choice as well as for the allocation of wealth across assets given the choice of which assets to hold" (Hubbard, 1985, p59).

Scholz (1994) examined the potential impact of taxation on the changes in portfolio patterns around tax reforms in 1986 in the US. Under The Tax Reform Act of 1986 (TRA), the top marginal income tax rate was significantly cut from 50% to 28%, while the personal tax base was broadened[37]. By using the data from Surveys of Consumer Finances conducted in 1983 and 1989, Scholz (1994) carried out an inter-temporal analysis and found some evidence that households shiftted toward mortgage borrowing and away from other type of debts, there were only relatively small shifts among other asset categories. It seems that the TRA did not significantly affect household portfolio decisions even though the marginal tax rates facing many households were affected. The possible explanation could be that it takes time for the households to adjust their portfolios. A three-year period after the tax reform took place may not be sufficient for

[37] "for example, TRA eliminated the reduction for state and local sales taxes, eliminated the exclusion for realized capital gains, and restricted eligibility for tax-deductible Individual Retirement Account contributions" (Scholz, 1994, p219-p220).

considerable changes in portfolio structures to be observable (Gordon, 1994; Poterba, 2002b). However, taxes itself "may be an important factor shaping the structure of household portfolios" (Scholz, 1994, p239), because in both years it was found that households facing high marginal tax rates were more likely to hold Tax-exempt bonds and IRAs and Keoghs which were tax preferred.

Samwick (2000) also examined how taxation affects the portfolio structure, concentrating particularly on the change in the ownership of the assets over the last two decades in the US. He studied the series of tax reforms over that period and concluded it was not clear that one could attribute the time-series changes in household portfolio allocation to the series of changes in marginal tax rates.

Poterba and Samwick (2003) used time-series changes in tax rates as well as cross-sectional variations in tax rates to explore the relationship between taxation and portfolio choices in the Surveys of Consumer Finances over 1983, 1989, 1992, 1995 and 1998. They used Probit and Tobit models to estimate the ownership of eight different assets and portfolio shares respectively. Similar covariates were included in the estimation as those in Feldstein (1976). While controlling for income and wealth, Poterba and Samwick (2003, p5) found marginal tax rates had "important effects on asset allocation decisions", and the effects were substantial on the probability of owning ordinary stocks, tax-exempt bonds or allocating assets in a tax-deferred account. Compared with their findings on the asset ownership, their studies suggested that the impact of taxation on the proportion of wealth invested in different categories of assets is weaker.

Partly due to the shortage of valuable information on the household portfolio composition in countries other than the US, not much work has been implemented interntionally on the relationship between taxation and portfolio allocation. One exception is Agell and Edin (1990) on marginal taxation and asset portfolios in Sweden. They used the household data from the annual Swedish income distribution survey and found significant impact of taxation on portfolio decisions. One policy implication of this study was also explored in the way that an increase of one percentage point in the marginal tax rate on interest and dividend income could boost the proportion of net wealth invested in common stocks by two percentage, in other words, increasing from 20 percentage to 20.4 percentage.

Stephens and Ward-Batts (2004) explored the effect of separate taxation on the intra-household portfolio allocation in the UK, where the switch to individual taxation from joint taxation took place in 1990. After 1990 UK households had the opportunity to reallocate their capital income to their partner with lower earnings in order to reduce the tax burden. They found some significant impact of this decision as households took advantage to reduce their tax burden.

Very recently, Alan *et al.* (2010) carried out similar studies related to the Canadian's individual taxation and portfolio allocation, using individual dataset from the Canadian Survey of Financial Security. As for the UK, Canadian couples "with the same household income can face different effective tax rates on capital income when labour income is distributed differently within households" (Alan *et al.,* 2010, p19). They were able to estimate the impact of taxation on portfolio allocations under the Canadian individual taxation system. They found "statistically significant but economically modest responses to differential taxation" (Alan *et al*., 2010, p19).

Other work includes Hochguertel *et al.* (1997) paper which used Netherlands data to explore the effect of taxation on portfolio choice. They concluded that the marginal tax rate and individual wealth were the key determinants of household portfolio allocations.

In sum, there has been a good deal of research which examines the impact of taxation on portfolio choices, especially in the US. These empirical studies suggested that taxation had a significant impact on the ownership for different categories of assets, whereas conditional on the ownership, it had limited impact on the proportion of investment in different classes of assets. Our research differs from the existing literature in the way that we only focus on two classes of assets, namely the risk-free assets and the risky assets[38], and concentrate on examine the effect of changes in tax on household risky assets choice in the UK.

5.3 Tax reform in the UK during 1999 and 2001

The following Table 5.1 presents the income tax rates and capital gain tax rates before, during and after the 1999-2001 tax reform in the UK.

Before the tax reform took place, capital gain tax rates and the labour income tax rates are exactly the same (the lower rate, basic rate and higher rate are 20%, around 24%, 40% respectively from 1995 to1999). While saving income and dividends income are taxed at the exactly same rate during 1996 and 1999 (the lower rate, basic rate and

[38] In this research, the liquid financial wealth is defined to include both risky assets and risk free assets. According to classification in BHPS, the former consist of National Savings Certificates, Premium Bonds, Unit Trusts/Investment Trusts, Personal Equity Plan, Shares (UK or foreign), National Savings bonds (Capital, Income or Deposit), and other investments (government or company securities). The risk free assets include saving or deposit account (with a bank, post office or building society), National Savings Bank (Post Office), TESSA or ISA. Income Tax Personal Allowances and Reliefs

higher rate are 20%, 20%, 40% respectively). As can be seen, saving income and dividends income are slightly less taxed before the 1999-2001 tax reform.

During the first year of the tax reform, the starting income tax rate, which was previously named as lower income tax rate, were dropped from 20% to 10% for labour income, saving income and dividends. Furthermore, for dividends income, not only the starting tax rate was reduced but also the basic tax rate was dropped from 20% to 10%, as well as the higher tax rate which was dropped from 40% to 32.5%. In comparison, for capital gain tax, just the basic rate was cut slightly from 23% to 20%, and for income the starting and the higher remained at 20% and 40% respectively. Hence, in 1999-2000, the tax reform focused on cutting the income tax rate.

In 2000-2001, the capital gain tax reform took place. The starting rate for capital gain tax was cut dramatically from 20 percentage to 10 percentage, while the basic and the higher rate was kept unchanged at 20% and 40% respectively. In contrast, all the rates for income tax on labour income, saving income and dividends income remained unchanged, except the basic rate for labour income was reduced slightly from 23 percentage to 22 percentage.

After this tax reform on income tax and capital gain tax in 1999-2001, all the tax rates remained exactly the same during 2001 and 2008.

Table 5. 1:Income tax rates and capital gain tax rates before, during and after the 1999-2001 tax reform

		Income Tax						Capital Gain Tax		
	financial year	IncomeTax Personal Allowances and Reliefs (£)	Bands of taxable income (£)		rate of income tax (%) labour income	saving income	dividends	Annual exempt amount (£)	rate of capital gain tax	(%)
Pre-reform	1995-1996									
		3,525	1-3,200	lower rate	20	20	20	6,000	lower rate	20
			3,201-24,300	basic rate	**25**	**25**	**20**		basic rate	**25**
			over 24,300	higher rate	40	40	40		higher rate	40
	1996-1997									
		3,765	1-3,900	lower rate	20	20	20	6,300	lower rate	20
			3,901-25,500	basic rate	**24**	**20**	**20**		basic rate	**24**
			over 25,500	higher rate	40	40	40		higher rate	40
	1997-1998									
		4,045	1-4,100	lower rate	20	20	20	6,500	lower rate	20
			4,101-26,100	basic rate	**23**	**20**	**20**		basic rate	**23**
			over 26,100	higher	40	40	40		higher	40

			rate						rate	
	1998-1999									
		4,195	1-4,300	lower rate	20	20	20	6,800	lower rate	20
			4,301-27,100	basic rate	**23**	**20**	**20**		basic rate	**23**
			over 27,100	higher rate	40	40	40		higher rate	40

	Financial year	Income Tax						Capital Gain Tax		
		IncomeTax Personal Allowances and Reliefs (£)	Bands of taxable income (£)		rate of income tax (%)			Annual exempt amount (£)	rate of capital gain tax	
					labour income	saving income	dividends			(%)
Tax reform	1999-2000									
		4,335	1-1,500	starting rate	10	10	10	7,100	starting rate	20
			1,501-28,000	basic rate	**23**	**20**	**10**		basic rate	**20**
			over 28,000	higher rate	40	40	**32.5**		higher rate	40
	2000-2001									
		4,385	1-1,520	starting rate	10	10	10	7,200	starting rate	**10**
			1,521-28,400	basic rate	**22**	**20**	**10**		basic rate	**20**
			over 28,400	higher rate	40	40	**32.5**		higher rate	40

	financial year	Income Tax						Capital Gain Tax		
		IncomeTax Personal Allowances and Reliefs (£)	Bands of taxable income (£)		rate of income tax (%)			Annual exempt amount (£)	rate of capital gain tax (%)	
					labour income	saving income	dividends			
Post-reform	2001-2002									
		4,535	1-1,880	starting rate	10	10	10	7,500	starting rate	10
			1,881-29,400	basic rate	22	20	10		basic rate	20
			over 29,400	higher rate	40	40	32.5		higher rate	40
	2002-2003									
		4,615	1-1,920	starting rate	10	10	10	7,700	starting rate	10
			1,921-29,900	basic rate	22	20	10		basic rate	20
			over 29,900	higher rate	40	40	32.5		higher rate	40
	2003-2004									
		4,615	1-1,960	starting rate	10	10	10	7,900	starting rate	10
			1,961-30,500	basic rate	22	20	10		basic rate	20
			over 30,500	higher rate	40	40	32.5		higher rate	40
	2004-2005									
		4,745	1-2,020	starting rate	10	10	10	8,200	starting rate	10
			2,021-31,400	basic rate	22	20	10		basic rate	20

		over 31,400	higher rate	40	40	32.5		higher rate	40
2005-2006									
	4,895	1-2,090	starting rate	10	10	10	8,500	starting rate	10
		2,091-32,400	basic rate	22	20	10		basic rate	20
		over 32,400	higher rate	40	40	32.5		higher rate	40

5.4 Impact of taxation on individual's risky asset choice: theoretical considerations

Taxation can have an impact on an individual's asset allocations by two approaches (King and Leape, 1998). The first approach is that among different asset classes with different tax preference, individuals who have different effective tax rates can choose to invest in those assets which can maximise their post-tax income. Empirical studies (e.g.:King and Leape, 1998, p176) suggest that individuals who have to pay high marginal tax rates tend to hold tax-exempt assets and/or tax preferred assets, such as municipal bonds and corporate equity, whereas the holders of taxed assets, for example, the holders of "liquid and less liquid savings" are found to be the individuals who face low marginal tax rates. The second approach is that the tax will have an impact on the demand for risky assets, but this impact is theoretically ambiguous (King and Leape, 1998, p177). Tobin (1958, p81) explained that if an risk averse individual could only invest in two assets, a risk-free asset with no yield and a risky asset whose return was normally distributed, then introducing a tax on "interest income and capital gains alike, with complete loss offset provisions" would cause the individual to invest a higher proportion of wealth in risky asset. Later, Mossin (1968) found that as long as the individual had a concave utility function and the risk-free asset with no yield, the impact of tax on risky asset allocations would be positive, no matter whether the risky asset's return followed a normal distribution or not. However, this impact of a proportional taxation on risky asset allocation would be ambiguous if the assumption that a risk-free asset had no yield does not hold (Feldstein, 1976, p633).

The following section provides a modified theoretical framework to analyse the effect caused by a change in tax rates. We separate this effect into two sub-effects, namely, the substitution effect and the wealth effect. These two effects will work together to determine the overall impact of taxation on an individual's portfolio allocation.

The following Figure 5.1 is used to illustrate the impact of tax reforms from a theoretical perspective. Suppose that we have a rational, risk-averse individual who wants to maximize his utility over wealth. He can choose to invest in two assets, namely the risk-free asset and the risky asset. The after-tax net return from risk-free asset is denoted as $E(R^F)$. The after-tax net return on risky asset is denoted as $E(R)$ which is the sum of after tax net return on capital gains, $E(R_c)$ and after-tax net return on dividends, $E(R_d)$. Suppose the individual has an initial wealth of W_t at time *t* and after he invests all the initial wealth in risk-free asset and risky asset, his total wealth at time t+1 is plotted in the diagram at W_0C_0. The α axis represents his risky asset share. So if he invests all of his initial wealth in risk-free asset (α =0), then his total wealth at time t+1 is W_0which is on the W axis, and the standard deviation of this portfolio's return is zero ($\sigma(R^F + R_c + R_d) = 0$). As α increases, the expected total wealth at time t+1 will increase as well as the riskiness of the portfolio's return. As we can see the individual's indifference curves have been also drawn on the diagram. The tangent point E_0 is the optimal point for this individual at time t+1 and the corresponding risky asset share is α_0 .

Now suppose the income tax rate on labour income, saving income and dividends are all reduced at time t, while the capital gain tax remains the same. Hence the after-tax net return on the risk-free asset, (R^F) , will increase. The after tax net return on dividends,$E(R_d)$, will also increase, as well as $\sigma(R_d)$. We keep the initial wealth W_t unchanged. So the opportunity locus will shift upwards from W_0C_0 to W_1C_1 and the line W_1C_1 is steeper and the investor will shift from point E_0 to point E_1. The line OA_0will rotate to OA_1. As we mentioned above, there are two effects involved in this process, namely, the substitution effect and the wealth effect. The substitution effect suggests that if the return from the risky asset increases, the investor's portfolio will be tilted towards the risky asset. Since at time t, the dividend income tax is reduced, so the after-tax net return on the risky asset, $E(R)$,which is the sum of $E(R_c)$ and $E(R_d)$ will increase. Hence, the substitution effect will induce the investor shift from E_0 to $E_1{}'$ and α_0 will increase to $\alpha_1{}'$, whereas the wealth effect will have the reverse impact. The increase in $E(R)$ will induce the investor to hold a relatively conservative portfolio, in other words, the investor will shift from $E_1{}'$ to E_1 and $\alpha_1{}'$ will be reduced to α_1. Since these two effects on risky asset holdings are in opposite directions, the overall effect is ambiguous. The diagram below just presents one scenario where the wealth effect dominates.

Now suppose not only the income tax rates are all reduced at time t, but also the capital gain tax is dropped. If we still keep the initial wealth W_t unchanged, then the effect of the capital gain tax change will move the opportunity locus upwards from W_1C_1 to W_1C_2. The investor will shift from point E_1 to point E_2. The line OA_1will shift to OA_2. Similarly, this effect of the capital gain tax can also be broken down into the substitution effect and the wealth effect. If the substitution effect dominates, then this decrease in capital gain tax will result in an increase in the risky asset share, α. The diagram below presents the second scenario when the wealth effect dominates. Hence, as we can see that this decrease in capital gain tax leads to a decrease in α.

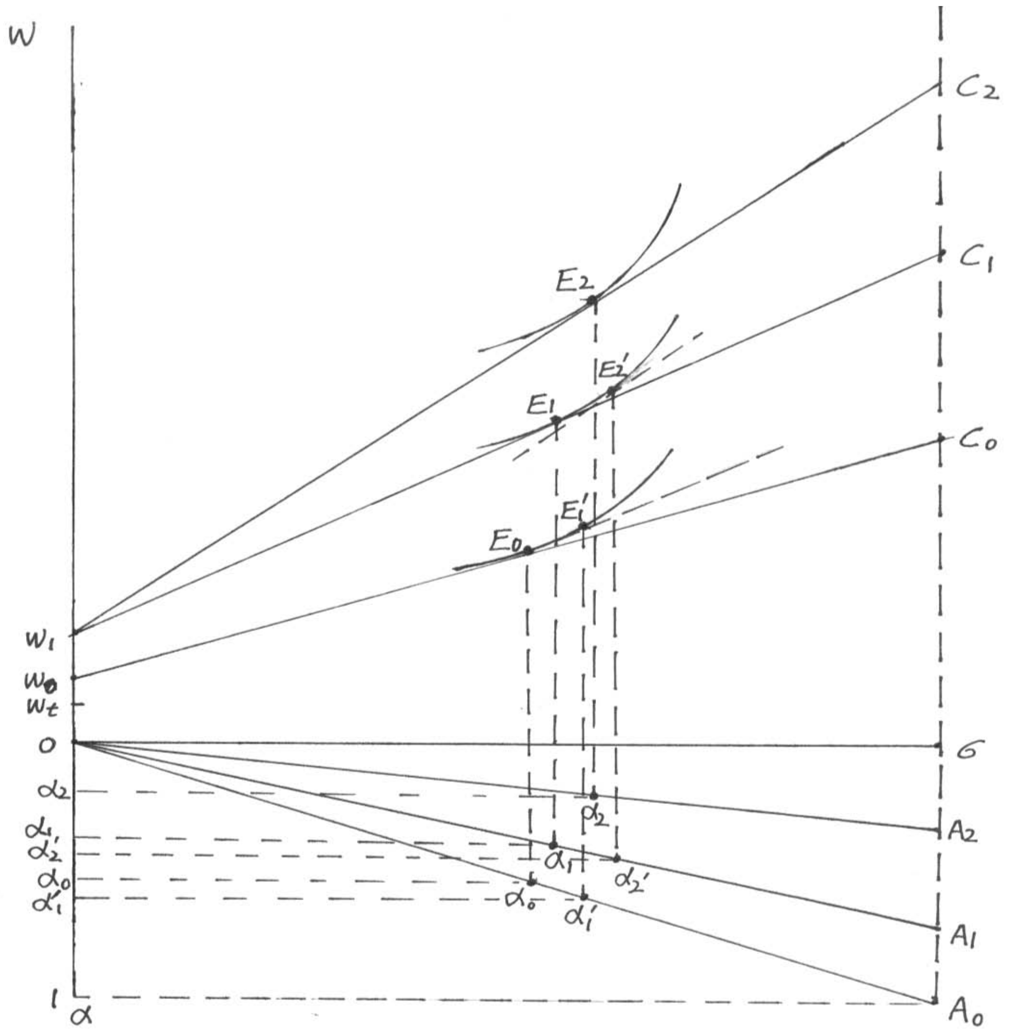
To sum up, from the theoretical perspective, the impact of an income tax change and a capital gain tax change on the risky asset share is ambiguous. The overall effect depends on which effect is in the dominant position, the substitution effect or the wealth effect. The following Table 5.2 summarize these effects. As we can see, if income tax falls and the substitution effect is greater than the wealth effect, risky asset share increases. If income tax falls and the substitution effect is less than the wealth effect, risky asset share decreases. Similarly, if capital gains tax falls and the substitution effect is greater than the wealth effect, risky asset share increases. If capital gains tax falls and the substitution effect is less than the wealth effect, risky asset share decreases.

Table 5. 2: The overall effect of the fall in tax

	Income tax falls	capital gain tax falls
α increases	substitution effect>wealth effect	substitution effect>wealth effect
α decreases	substitution effect<wealth effect	substitution effect<wealth effect

As mentioned before, this chapter is to examine the taxation effect of income tax changes and capital gain tax changes on the individual's asset allocation in the UK. In section 5.3, we discussed the income tax rates and capital gain tax rates before, during and after the 1999-2001 tax reform and we can simplify the tax policy changes during 1999 and 2001 into two parts. The first part, tax year 1999-2000, can be regarded as the year in which income tax reform took place and the tax year 2000-2001 can be regarded as the year in which capital gain tax reform took place. Later in section 5.6, we will explain our empirically results from the theoretically perspective.

Figure 5. 1:Impact of taxation on individual's risky asset choice



5.5 Data and methods

5.5.1 Control and treatment groups (Difference-in-Differences (DD) estimation)

5.5.1.1: Definition of control and treatment groups under DD methods

In this chapter, we use individual level data from the British Household Panel Survey (BHPS) for years 1995 and 2000. Our data are constructed from both the household files as well as individual files of the BHPS. We will use this data to examine the impact of income tax and capital gain tax on portfolio shares in risky assets by using the Difference-in-Differences method.

The simple case consists of two groups and two time period. The treatment group is exposed to a treatment in the second period only and the control group is not exposed to the treatment at either period. DD method involves subtracting the average gain in the control group from the average gain in the treatment group across both periods. This method "removes biases in second period comparisons between the treatment and control group that could be the result from permanent differences between those groups, as well as biases from comparisons over time in the treatment group that could be the result of trends" (Wooldridge, 2007).

5.5.1.1.1: Definition of control and treatment groups when estimating the effect of income tax

We firstly set up the DD estimation for the effect of income tax on an individual's risky asset shares. There are four DD estimations involved in this process. The first one is to examine the effect of paying income tax on an individual's risky asset shares in the short run (years 1995-2000), and the second one refers to the short-run effect of reduced marginal income tax due to the income tax reform in the tax year 1999-2000. The third one and the fourth one are similar to the first one and the second one respectively, but they look at the long-run effect from 1995 to 2005.

For all these four DD estimations, we use individual total annual income which includes labour, interest and dividend income to select the treatment and control groups. For the first DD estimation, we select our control group as respondents who were not paying income tax in both years. Hence the control group is made up of respondents whose gross incomes were below £3525 and £4385 in 1995 and 2000 respectively. Whereas the treatment group consists of individuals whose gross incomes were below £3525 in 1995 and above £4385 in 2000. These are the thresholds for marginal tax rates which changed over the two periods. They are the income tax personal allowances for each of these two years. Hence our treatment group consists of individuals who were not paying income tax in 1995 and were paying income tax in 2000. Our final sample includes 1562 individuals (3124 observations) who responded to both surveys in 1995 and 2000 and on which we have data on savings and investment. There are 1160 individuals in the control group and 402 individuals in the treatment group.

The following Table 5.3 suggests that the average risky asset allocation for the treatment group is the same as the average risky asset allocation for the control group in 1995, which is 14 percent. In 2000, the average risky asset allocation for the control group remains at 14 percent, whereas the average risky asset allocation for the treatment group falls to 11 percent. The average net liquid wealth decreases for both groups from 1995 to 2000. The average personal debt increases for both groups from 1995 to 2000. Similarly, this pattern of change has been found in gross house value and gross labour income. The following Table also suggests that on average, respondents in the treatment group are much younger than respondents in the control group. The average age for the treatment group in 1995 is 27.45 and it increases to 32.65 in 2000. The average age for the control group in 1995 is 53.62 and it increases to 58.84 in 2000. In the treatment group, 38 percent of the respondents are male, whereas in the control group, 32 percent of the respondents are male.

Table 5. 3:Descriptive statistics for treatment group and control group (DD for the effect of paying income tax, 1995-2000)

	Treatment group		**Control group**	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.14	(0.30)	0.14	(0.30)
allocation2000	0.11	(0.27)	0.14	(0.30)
netliquidwealth1995	2.44	(13.58)	6.78	(20.23)
netliquidwealth2000	1.33	(14.92)	5.54	(16.31)
personaldebt1995	0.55	(2.66)	0.19	(0.70)
personaldebt2000	2.26	(4.06)	0.45	(1.98)
housing1995	45.88	(50.59)	37.79	(44.13)
housing2000	64.95	(78.03)	56.02	(77.29)
grosslabourincome1995	0.61	(1.05)	0.22	(0.69)
grosslabourincome2000	12.74	(6.74)	0.46	(0.98)
age1995	27.45	(11.77)	53.62	(18.72)
age2000	32.65	(11.76)	58.84	(18.72)
sexdum1995	0.38	(0.49)	0.32	(0.47)

sexdum2000	0.38	(0.49)	0.32	(0.47)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the second DD estimation which examine the short run effect of reduced marginal income tax due to the income tax reform in tax year 1999-2000. If the individual did not pay income tax in 1995 and 2000, then he/she is classified as in the control group. If the individual paid income tax in 1995 and 2000, then he/she is classified as in the treatment group. For the second estimation, there are 5018 observations. In other words, there are 2509 individuals (5018 observations) who responded to both surveys in 1995 and 2000 and on which we have data on savings and investment. There are 1160 individuals in the control group and 1349 individuals in the treatment group.

The following Table 5.4 suggests that from 1995 to 2000 the average risky asset allocation for the treatment group increases from 20 percent to 23 percent and the average risky asset allocation for the control group remains the same at 14 percent. The average net liquid wealth remains the same for treatment group and it decreases for control group from £6,780 to £5,540. The average personal debt increases for both groups from 1995 to 2000. Similarly, this pattern of change has been found in gross house value and gross labour income. The following Table also suggests that on average, respondents in the treatment group are younger than respondents in the control group. The average age for the treatment group in 1995 is 35.28 and it increases to 40.47 in 2000. The average age for the control group in 1995 is 53.62 and it increases to 58.84 in 2000. In the treatment group, 56 percent of the respondents are male, whereas in the control group, 32 percent of the respondents are male.

Table 5. 4: Descriptive statistics for treatment group and control group (DD for the effect of reduced marginal income tax, 1995-2000)

Variables	Treatment group Mean	Treatment group Std. Dev.	Control group Mean	Control group Std. Dev.
allocation1995	0.20	(0.34)	0.14	(0.30)
allocation2000	0.23	(0.35)	0.14	(0.30)
netliquidwealth1995	5.99	(41.23)	6.78	(20.23)
netliquidwealth2000	5.99	(27.55)	5.54	(16.31)
personaldebt1995	1.41	(3.29)	0.19	(0.70)
personaldebt2000	2.55	(5.47)	0.45	(1.98)
housing1995	55.38	(44.16)	37.79	(44.13)
housing2000	95.17	(86.55)	56.02	(77.29)
grosslabourincome1995	15.46	(9.86)	0.22	(0.69)
grosslabourincome2000	21.11	(13.37)	0.46	(0.98)
age1995	35.28	(10.14)	53.62	(18.72)
age2000	40.47	(10.14)	58.84	(18.72)
sexdum1995	0.56	(0.50)	0.32	(0.47)
sexdum2000	0.56	(0.50)	0.32	(0.47)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the third DD estimation, we look at the long run effect of paying income tax from 1995 to 2005. Using the income allowances which are £3525 in 1995 and £4895 in 2005, we define control group and treatment group. The control group refers to individuals whose gross incomes were less than income allowance in 1995 and 2005, and treatment group refers to individuals whose gross income was less than the income allowance in 1995 but was greater in 2005. And finally, we have 1766 individuals and 3532 observations in that sample. There are 1258 individuals in the control group and 508 individuals in the treatment group.

The following Table 5.5 suggests that from 1995 to 2005 the average risky asset allocation for the treatment group increases from 12 percent to 15 percent and the average risky asset allocation for the control group drops from 19 percent to 13 percent. The average net liquid wealth drops from £1,960 to £1,040 for treatment group and it decreases from £15,460 to £11,590 for control group. The average personal debt increases for both groups from 1995 to 2005. Similarly, this pattern of change has been found in gross house value and gross labour income. The following Table also suggests that on average, respondents in the treatment group are much younger than respondents in the control group. The average age for the treatment group in 1995 is 28.28 and it increases to 38.50 in 2005. The average age for the control group in 1995 is 54.93 and it increases to 65.15 in 2005. In the treatment group, 40 percent of the respondents are male, whereas in the control group, 33 percent of the respondents are male.

Table 5. 5: Descriptive statistics for treatment group and control group (DD for the effect of paying income tax, 1995-2005)

	Treatment group		**Control group**	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.12	(0.28)	0.19	(0.33)
allocation2005	0.15	(0.32)	0.13	(0.30)
netliquidwealth1995	1.96	(11.21)	15.46	(45.91)
netliquidwealth2005	1.04	(12.84)	11.59	(50.83)
personaldebt1995	0.51	(1.71)	0.24	(1.08)
personaldebt2005	3.13	(5.78)	0.44	(2.34)
housing1995	49.55	(50.68)	50.71	(59.95)
housing2005	147.15	(125.44)	136.03	(158.51)
grosslabourincome1995	0.52	(1.00)	0.23	(0.72)
grosslabourincome2005	18.52	(11.99)	0.25	(0.94)
age1995	28.28	(10.22)	54.93	(16.64)
age2005	38.50	(10.22)	65.15	(16.63)
sexdum1995	0.40	(0.49)	0.33	(0.47)
sexdum2005	0.40	(0.49)	0.33	(0.47)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the fourth DD estimation, we examine the long run effect of reduced marginal income tax due to income tax reform in tax year 1999-2000. By using income allowances which are £3525 and £4895 in 1995 and 2005 respectively, we define control group as a group of individuals who did not pay income tax in 1995 and 2005, and treatment group as a group of individuals who paid income tax in 1995 and 2005. We have 2497 individuals and 4994 observations in that sample. There are 1258 individuals in the control group and 1239 individuals in the treatment group.

The following Table 5.6 suggests that from 1995 to 2005 the average risky asset allocation for the treatment group drops from 19 percent to 18 percent and the average risky asset allocation for the control group drops from 19 percent to 13 percent. The average net liquid wealth increases from £4,570 to £6,060 for treatment group and it decreases from £15,460 to £11,590 for control group. The average personal debt increases for both groups from 1995 to 2005. Similarly, this pattern of change has been found in gross house value and gross labour income. The following Table also suggests that on average, respondents in the treatment group are younger than respondents in the control group. The average age for the treatment group in 1995 is 34.98 and it increases to 45.18 in 2005. The average age for the control group in 1995 is 54.93 and it increases to 65.15 in 2005. In the treatment group, 55 percent of the respondents are male, whereas in the control group, 33 percent of the respondents are male.

Table 5. 6: Descriptive statistics for treatment group and control group (DD for the effect of reduced marginal income tax, 1995-2005)

	Treatment group		Control group	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.19	(0.33)	0.19	(0.33)
allocation2005	0.18	(0.33)	0.13	(0.30)
netliquidwealth1995	4.57	(25.23)	15.46	(45.91)
netliquidwealth2005	6.06	(32.93)	11.59	(50.83)
personaldebt1995	1.36	(2.74)	0.24	(1.08)
personaldebt2005	3.53	(15.36)	0.44	(2.34)
housing1995	56.80	(47.04)	50.71	(59.95)
housing2005	194.05	(137.36)	136.03	(158.51)
grosslabourincome1995	15.14	(8.99)	0.23	(0.72)
grosslabourincome2005	25.56	(18.82)	0.25	(0.94)
age1995	34.98	(9.39)	54.93	(16.63)
age2005	45.18	(9.39)	65.15	(16.63)
sexdum1995	0.55	(0.50)	0.33	(0.47)
sexdum2005	0.55	(0.50)	0.33	(0.47)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

5.5.1.1.2: Definition of control and treatment groups when estimating the effect of capital gain tax

Now we set up the DD estimation for the effect of the capital gain tax on an individual's risky asset shares. There are also four DD estimations involved in this process. The first one is to examine the effect of paying capital gain tax on individual's risky asset shares in the short run (1995-2000), and the second one refers to the short-run effect of reduced marginal capital gain tax due to the tax reform in the tax year 2000-2001. The third one and the fourth one are similar to the first one and the second one respectively, but they look at the long-run effect from 1995 to 2005.

Because we use the BHPS data, we could not find direct information on individual's capital gains in the corresponding year, so in this research, we assume that the gross return on capital investment is 10 percent. Then the individual' "capital gain" equals to the product of 10 percent multiply by the amount of individual's total risky assets. If the capital gain exceeds the capital gain allowance in that year, this individual would be considered as a "capital gain tax payer" in that year in this research.

Hence, for all these four DD estimations, we use this definition of "capital gains" and "capital gain tax payer" to select the treatment and control groups. For the first DD estimation, we select our control group as respondents who were not paying capital gain tax in both 1995 and 2000. Hence the control group is made up of respondents whose capital gain was below £6000 and £7200 in 1995 and 2000 respectively. Whereas the treatment group consists of individuals whose capital gain was below £6000 in 1995 and above £7200 in 2000. The £6000 and £7200 are the capital gain allowances for 1995 and 2000 respectively. Hence our treatment group consists of individuals who were not paying capital gain tax in 1995 and were paying capital gain tax in 2000. Our final sample includes 3911 individuals who responded to both surveys in 1995 and 2000 and on which we have data on savings and investment. There are 3885 individuals in the control group and 26 individuals in the treatment group.

The following Table 5.7 suggests that from 1995 to 2000 the average risky asset allocation for the treatment group increases from 53 percent to 84 percent and the average risky asset allocation for the control group increases from 16 percent to 17 percent. The average net liquid wealth increases from £41,480 to £144,070 for treatment group and it decreases from £4,380 to £3,840 for control group. From 1995 to 2000 the average personal debt decreases for the treatment group and it increases for the control group. Gross house value increases for both groups from 1995 to 2000 and a similar pattern of change can be found in gross labour income. The following Table also suggests that on average, respondents in the treatment group are older than respondents in the control group. The average age for the treatment group in 1995 is 53.24 and it increases to 57.85 in 2000. The average age for the control group in 1995 is 42.30 and it increases to 46.97 in 2000. In the treatment group, 50 percent of the respondents are male, whereas in the control group, 44 percent of the respondents are male.

Table 5. 7: Descriptive statistics for treatment group and control group (DD for the effect of paying capital gains tax, 1995-2000)

	Treatment group		Control group	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.53	(0.37)	0.16	(0.31)
allocation2000	0.84	(0.17)	0.17	(0.32)
netliquidwealth1995	41.48	(36.31)	4.38	(13.88)
netliquidwealth2000	144.07	(63.88)	3.84	(14.14)
personaldebt1995	0.43	(1.00)	0.76	(2.25)
personaldebt2000	0.29	(0.87)	1.57	(4.06)
housing1995	120.88	(62.00)	47.49	(44.65)
housing2000	232.69	(188.25)	72.27	(78.16)
grosslabourincome1995	11.97	(15.99)	7.35	(9.52)
grosslabourincome2000	14.35	(18.28)	10.53	(12.88)
age1995	53.24	(15.27)	42.30	(17.74)
age2000	57.85	(14.30)	46.97	(17.50)
sexdum1995	0.50	(0.51)	0.44	(0.50)
sexdum2000	0.50	(0.51)	0.44	(0.50)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the second DD estimation which examine the short run effect of reduced marginal capital gain tax due to the tax reform in tax year 2000-2001. If the individual did not pay capital gain tax in 1995 and 2000, then he/she is classified as in the control group. If the individual paid capital gain tax in 1995 and 2000, then he/she is classified as in the treatment group. For the second estimation, there are 7808 observations. In other words, there are 3904 individuals who responded to both surveys in 1995 and 2000 and on which we have data on savings and investment. There are 3885 individuals in the control group and 19 individuals in the treatment group.

The following Table 5.8 suggests that from 1995 to 2000 the average risky asset allocation for the treatment group increases from 82 percent to 84 percent and the average risky asset allocation for the control group increases from 16 percent to 17 percent. The average net liquid wealth decreases from £285,830 to £223,400 for treatment group and it decreases from £4,380 to £3,840 for control group. The average personal debt increases for both groups from 1995 to 2000. Similarly, this pattern of change has been found in gross house value. The average gross labour income deceases from £20,650 to £17,990 for the treatment group while it increases for the control group from 1995 to 2000. The following Table also suggests that on average, respondents in the treatment group are older than respondents in the control group. The average age for the treatment group in 1995 is 56.22 and it increases to 61.24 in 2000. The average age for the control group in 1995 is 42.30 and it increases to 46.97 in 2000. In the treatment group, 67 percent of the respondents are male, whereas in the control group, 44 percent of the respondents are male.

Table 5. 8: Descriptive statistics for treatment group and control group (DD for the effect of reduced marginal capital gains tax, 1995-2000)

Variables	Treatment group Mean	Std. Dev.	Control group Mean	Std. Dev.
allocation1995	0.82	(0.16)	0.16	(0.31)
allocation2000	0.84	(0.14)	0.17	(0.32)
netliquidwealth1995	285.83	(259.79)	4.38	(13.88)
netliquidwealth2000	223.40	(139.02)	3.84	(14.14)
personaldebt1995	0.78	(1.96)	0.76	(2.25)
personaldebt2000	2.63	(11.47)	1.57	(4.06)
housing1995	146.39	(76.21)	47.49	(44.65)
housing2000	203.68	(123.69)	72.27	(78.16)
grosslabourincome1995	20.65	(33.49)	7.35	(9.52)
grosslabourincome2000	17.99	(25.94)	10.53	(12.88)
age1995	56.22	(11.82)	42.30	(17.74)
age2000	61.24	(11.40)	46.97	(17.50)
sexdum1995	0.67	(0.50)	0.44	(0.50)
sexdum2000	0.67	(0.50)	0.44	(0.50)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the third DD estimation, we look at the long run effect of paying capital gain tax from 1995 to 2005. Using the capital gain allowances which are £6000 in 1995 and £8500 in 2005, we define control group and treatment group. The control group refers to individuals whose capital gain tax was less than capital gain allowance in 1995 and 2005, and treatment group refers to individuals whose capital gain was less than the capital gain allowance in 1995 but was greater in 2005. And finally, we have 2989 individuals and 5978 observations in that sample. There are 2828 individuals in the control group and 161 individuals in the treatment group.

The following Table 5.9 suggests that from 1995 to 2005 the average risky asset allocation for the treatment group increases from 71 percent to 73 percent and the average risky asset allocation for the control group drops from 11 percent to 10 percent. The average net liquid wealth increases from £82,780 to £101,570 for treatment group and it increases from £1,770 to £1,850 for control group. From 1995 to 2005 the average personal debt decreases for the treatment group and it increases for the control group. Gross house value increases for both groups from 1995 to 2005 and a similar pattern of change can be found in gross labour income. The following Table also suggests that on average, respondents in the treatment group are older than respondents in the control group. The average age for the treatment group in 1995 is 53.82 and it increases to 63.97 in 2005. The average age for the control group in 1995 is 40.89 and it increases to 51.11 in 2005. In the treatment group, 60 percent of the respondents are male, whereas in the control group, 41 percent of the respondents are male.

Table 5. 9: Descriptive statistics for treatment group and control group (DD for the effect of paying capital gains tax, 1995-2005)

	Treatment group		**Control group**	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.21	(0.32)	0.11	(0.27)
allocation2005	0.73	(0.26)	0.10	(0.27)
netliquidwealth1995	5.84	(12.49)	1.77	(7.28)
netliquidwealth2005	43.31	(48.46)	1.85	(14.37)
personaldebt1995	1.48	(3.31)	0.74	(2.10)
personaldebt2005	2.18	(9.40)	2.10	(9.74)
housing1995	78.16	(66.21)	46.59	(44.85)
housing2005	241.26	(142.32)	145.76	(133.09)
grosslabourincome1995	13.09	(13.40)	6.72	(8.60)
grosslabourincome2005	17.94	(21.83)	12.27	(16.24)
age1995	44.10	(14.06)	40.89	(16.58)
age2005	54.26	(14.03)	51.11	(16.57)
sexdum1995	0.56	(0.50)	0.41	(0.49)

sexdum2005	0.56	(0.50)	0.41	(0.49)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

For the fourth DD estimation, we examine the long run effect of reduced marginal capital gain tax due to tax reform in tax year 2000-2001. By using capital gain allowances which are £6000 and £8500 in 1995 and 2005 respectively, we define control group as a group of individuals who did not pay capital gain tax in 1995 and 2005, and treatment group as a group of individuals who paid capital gain tax in 1995 and 2005. We have 2974 individuals and 5948 observations in that sample. There are 2828 individuals in the control group and 146 individuals in the treatment group.

The following Table 5.10 suggests that from 1995 to 2005 the average risky asset allocation for the treatment group increases from 21 percent to 73 percent and the average risky asset allocation for the control group drops from 11 percent to 10 percent. The average net liquid wealth increases from £5,840 to £43,310 for treatment group and it increases from £1,770 to £1,850 for control group. From 1995 to 2005 the average personal debt increases for both groups from 1995 to 2005. Similarly, this pattern of change has been found in gross house value and gross labour income. The following Table also suggests that on average, respondents in the treatment group are older than respondents in the control group. The average age for the treatment group in 1995 is 44.10 and it increases to 54.26 in 2005. The average age for the control group in 1995 is 40.89 and it increases to 51.11 in 2005. In the treatment group, 56 percent of the respondents are male, whereas in the control group, 41 percent of the respondents are male.

Table 5. 10: Descriptive statistics for treatment group and control group (DD for the effect of reduced marginal capital gains tax, 1995-2005)

	Treatment group		Control group	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
allocation1995	0.71	(0.23)	0.11	(0.27)
allocation2005	0.73	(0.26)	0.10	(0.27)
netliquidwealth1995	82.78	(93.67)	1.77	(7.28)
netliquidwealth2005	101.57	(141.51)	1.85	(14.37)
personaldebt1995	0.63	(2.71)	0.74	(2.10)
personaldebt2005	0.50	(1.89)	2.10	(9.74)
housing1995	108.86	(74.77)	46.59	(44.85)
housing2005	290.41	(161.74)	145.76	(133.09)
grosslabourincome1995	11.32	(14.73)	6.72	(8.60)
grosslabourincome2005	11.73	(24.34)	12.27	(16.24)
age1995	53.82	(12.46)	40.89	(16.58)
age2005	63.97	(12.48)	51.11	(16.57)
sexdum1995	0.60	(0.49)	0.41	(0.49)
sexdum2005	0.60	(0.49)	0.41	(0.49)

Note: Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £1,000 in the above table.

5.5.1.2: The fundamental concept of DD estimation

In order to explain the concept behind the difference-in-difference (DD) estimation, we use the DD estimation which aims to examine the short-run effect of reduced marginal income tax due to income tax reform in the tax year 1999-2000. Suppose PA1 and PA2 represents the average portfolio share in risky assets for the control group in 1995 and 2000 respectively, and PA3 and PA4 denotes the average portfolio share in risky assets for the treatment group in 1995 and 2000 respectively:

Table 5. 11: Simple illlustration for DD methods

	Control group (*dumtreatment*=0)	Treatment group (*dumtreatment*=1)
1995 (*timedummy*=0)	PA1	PA3
2000 (*timedummy=1*)	PA2	PA4

The change in portfolio share for the treatment group over 1995 and 2000 is *PA4-PA3*. Some of this change may be attributed to the change in the marginal income tax rates and the other part is due to external factors. The assumption we made for estimating the DD estimator is that individuals in the control group reflect those external non-tax factors in the change in their portfolio share, which is denoted as *PA2-PA1.* This "common trends" assumption is a fundamental concept of DD estimation. Therefore, an estimate of the impact of taxation on the portfolio allocation in the treatment group is *(PA4-PA3)-(PA2-PA1).* In other words, basically we need to compare the portfolio share change of an individual who experienced large cut in taxation with that of individuals who faced no cut in taxation, under the assumption that they would have reallocated their portfolio share in the same way and same amount in the absence of the marginal income tax rate change in 1999.

5.5.1.3 Regression-adjusted DD estimation

However, the "common trends" assumption may not be satisfied, because the control group and treatment group may "differ in time trends of either observable or unobservable characteristics or both" (Crossley and Jeon, 2007, p355). This means that the observable or unobservable group characteristics or both can explain the difference between the changes in portfolio shares which refers to *(PA4-PA3)-(PA2-PA1)*. A possible remedy is to carry out a regression-adjusted DD estimation. By controlling for the relevant and observable factors, this remedy would reduce the bias that is caused by the different changes over time in the observable characteristics between control group and treatment group (Meyer, 1995; Crossley and Jeon, 2007). Meyer (1995) also points out that compared with a simple DD estimation approach, this regression-adjusted DD estimation method would lead to more efficient estimates. Therefore, besides running the following simple DD regression,

$$\alpha_{it}^{*} = \beta_0 + \beta_1 \ dumtreatment_i + \beta_2 timedummy_t + \beta_3 (timedummy * dumtreatment)_{it} + \varepsilon_{it} \ ,$$

$\varepsilon_{it} \sim N(0, \sigma^2)$,

where $\alpha_{it} = \begin{bmatrix} 0 & if \alpha_{it}^{*} \leq 0 \\ \alpha_{it}^{*} & if \, 0 < \alpha_{it}^{*} \leq 1 \\ 1 & if \alpha_{it}^{*} > 1 \end{bmatrix}$,

we would also augment it with regression-adjusted DD estimation, which is specified as follows:

$$\alpha_{it}^{*} = \beta_0 + \beta_1 \ dumtreatment_i + \beta_2 timedummy_t + \beta_3 (timedummy * dumtreatment)_{it} + \beta_4 X_{it} +$$

ε_{it}, $\varepsilon_{it} \sim N(0, \sigma^2)$,

where

$$\alpha_{it} = \begin{bmatrix} 0 & if \alpha_{it}^{*} \leq 0 \\ \alpha_{it}^{*} & if \, 0 < \alpha_{it}^{*} \leq 1 \\ 1 & if \alpha_{it}^{*} > 1 \end{bmatrix} .$$

Since our risky asset allocation data are left censored at zero if the respondent does not invest in the risky assets, and are right censored at one if the respondent invest all his/her wealth in the risky assets, we estimate the models via a Tobit regression which allows for data censoring both at zero and one. In this estimation, the portfolio share, α_{it}^{*}, is the latent variable which indicates the proportion of personal wealth that would notionally be invested in the risky assets. We control for a series of socioeconomic and demographic variables, such as net liquid wealth, personal debt, housing, gross labour income, age and gender[39].

Note that Gross labour income *(Gross labour income)* refers to the households' annual labour income only. Income from savings and investments are not included in order to avoid potential endogeneity problem of the portfolio share and income variables; *dumtreatment* is a dummy variable which equals one if the respondent is in the treatment group. It captures "possible differences between the treatment and control groups prior to the policy change" (Wooldridge, 2007, p3). The dummy variable *timedummy* equals zero for 1995 and equals one otherwise. This dummy variable captures "aggregate factors that would cause changes in y even in the absence of a policy change" (Wooldridge, 2007, p3). Its coefficient, β_2, is expected to be negative in this case if the respondents foresee stock market crash and economics recession which starts from January of 2000. The coefficient, β_3, for *timedummy*dumtreatment* would suggest whether the income tax or the capital gain tax had an positive, negative or no impact on the individuals' risky asset shares.

[39] , Please refer to chapter 3.3.2 for definitions of each variable. Note, *Gross income (GROSSINCOME)* refers to the households' annual labour income only. Income from savings and investments are not included in order to avoid potential endogeneity problem of the portfolio share and income variables.

5.5.2 Standard Tobit estimation with additional variable of marginal tax rate

In this research, we will also develop another way to examine the effect of the marginal tax rate on household asset allocation. We modify the Tobit estimation as follows:

$$\alpha^*_{2000i} = (1-\beta_0)\alpha_{1999i} + \beta_1\ marginaltaxrate_{2000i} + \beta X_i + \varepsilon_i\,,\ \ \varepsilon_i \sim N(0,\sigma^2)\,,$$

where

$$\alpha_{2000i} = \begin{cases} 0 & if \alpha^*_{2000i} \le 0 \\ \alpha^*_{2000i} & if\, 0 < \alpha^*_{2000i} \le 1 \\ 1 & if \alpha^*_{2000i} > 1 \end{cases}.$$

In this estimation, the portfolio share, α^*_{2000i}, is the latent variable which indicates the proportion of personal wealth that would notionally be invested in the risky assets in 2000. We introduce an additional explanatory variable, the marginal tax rate in 2000 tocapture the impact of the marginal tax rate on household asset allocation. The variable X refers a series of control variable, such as net liquid wealth and age.

We estimate the marginal tax rate on ordinary saving and investment income for each respondent in the corresponding BHPS survey. This tax rate is not just an important element of tax reform in year 1999, but it also varies across individuals. While we use the respondents' income information, we have to overcome a potential endogeneity problem, because the marginal tax rate on ordinary saving and investment income for each respondent may itself be influenced by his/her portfolio allocations. An individual who allocates all his/her wealth in risky assets, such as corporate stocks and bonds, receives higher level of investment income and, consequently, he/she may face a higher marginal tax rate than an individual who saves the same value of wealth in a bank saving account. This is based on the assumption of risk-return trade-off theory which states that low level of risk is related to a low potential return, whereas a high level of risk is related to high potential return.

To "avoid" this problem, we adopt the method introduced by Poterba and Samwick' (2003). We, firstly, calculate the total tax liability of the respondent's basic income T(Y), and then calculate the total tax liability of the respondent's artificially incremented income T (Y+Δ), where Δ denotes an increment. Hence the respondent's marginal tax rate on ordinary saving and investment income equals [T (Y+Δ) - T(Y)]/ Δ, which is the difference between these two taxation liability over an increment. Because Poterba and Samwick (2003) point out that "the base amount and the increment must be unrelated to the households' portfolio allocation decision" so as to eliminate the endogeneity problem raised by marginal tax rate, we define the base level of income for a respondent, Y, as his/her labour income and artificially set his/her saving and investment income to zero. This choice of base level of income ensures it is unrelated to the portfolio allocation decision.

For the choice of the increment Δ, despite having relevant information and a dataset on respondent's income from dividends and interests, we have to adopt another method to ensure the increment to income is unrelated to the portfolio allocation decision. We take the greater value between 5% of the respondent's total savings and investments assets, and £100. This 5% is chosen for an approximation of the annual nominal return on total saving and investment assets. If the increment "moves the individual from one tax bracket to another" (Poterba and Samwick, 2003, p20), the marginal tax rate we estimated here would be an average of the marginal tax rates for those two tax brackets. At the end, by using the basic level of income and the increment, we are able to calculate the marginal tax rate on any additional pound of ordinary savings and investment income. Specifically, the personal income allowance and reliefs we use for 2000-2001 is £4,385. The bands of taxable income are £1-£1,520, £1,521-£28,400, over £28,400. The starting rate, basic rate and higher rate for labour income is 10 percent, 22 percent and 40 percent respectively. We use these rates when calculating T(Y). When we calculate T (Y+Δ), we use the same tax bracket, use the same tax rates for labour income, and use the average tax rates for saving income and dividends. The latter is calculated as follows. We know in 2000-2001 for saving income the starting rate, basic rate and higher rate is 10 percent, 20 percent and 40 percent, respectively. For dividends the starting rate, basic rate and higher rate is10 percent, 10 percent and 32.5 percent respectively. If we take the average, then we get the average starting rate, average basic rate and average higher rate for saving income and dividends is at 10 percent, 15 percent and 36 percent, respectively. Hence, we can calculate the total tax liability of the respondent's artificially incremented income T (Y+Δ).

In order to interpret the magnitude of the marginal tax rate effect on portfolio shares, we will calculate the marginal effects in the censored regression model. Greene (2000, p909) shows that the marginal effect of the explanatory variable x on the expected explained variable y is as follows:

$$\frac{\partial E[y \mid x_i]}{\partial x^k} = \beta^k * \Pr ob[a < y^* < b] = \sum_i [\varnothing(\frac{b-\beta x_i}{\sigma}) - \varnothing(\frac{a-\beta x_i}{\sigma})]\beta^k$$

where $\varnothing$ represents the cumulative standard normal distribution function. x^k is the *kth* explanatory variable for individual *i*. The marginal effect of x_i^k on the portfolio share of individual *i* is the product of the coefficient on x_i^k and the probability "that the latent variable for a given observation falls between the upper and lower limits associated with the tobit" (Poterba and Samwick, 2003, p22).

5.6 Estimation Results

In this section, we will first present and discuss the DD estimation results related to the short-run and long-run impact of the income tax reform on an individual's asset portfolio, followed by the impact of capital gain tax reform. Then we will estimate standard Tobit regression for 2000 to examine the marginal tax rate effect on the portfolio share in risky asset.

5.6.1 Effect of income tax on individual's asset allocation

5.6.1.1 Simple DD estimations for effect of income tax on risky asset shares

Table 5.12 presents the simple DD estimation results for the short run impact on the portfolio allocation of paying income tax and reduced marginal income tax due to tax reform in the tax year 1999-2000. The definition of the control group and treatment group for each DD estimation can be found in the section 5.5.1.1.1. As we can see, the coefficient of *timedummydumtreatment* is not statistically significant in the first model and the Chi-squared test for model specification has not been passed. We use likelihood-ratio chi-squared statistic to test the overall significance of our full model. As we can see from Table 5.12, the likelihood ratio chi-square statistic is 3.34 with a p-value of 0.3421, which suggests that we can not reject our null hypothesis that all coefficients are jointly equal to zero.

The second DD estimation results in Table 5.12 implies that the difference between the changes in the average portfolio share of the two groups over 1995 and 2000 could be due to the income tax reforms in 1999, if the "common trend" assumption holds. The reduced marginal income tax may have a positive impact on risky asset shares. However, typically the common trend would not hold and we have to augment this simple DD estimation with regression-adjusted DD estimation by controlling for relevant and observable factors. We will look at the augmented estimation later in section 5.6.1.2.

Table 5. 12:The simple DD estimation in tobit for the effect of paying income tax and for the effect of reduced marginal income tax (1995-2000)

Variables	**DD for the effect of paying income tax**	**DD for the effect of reduced marginal income tax**
Dumtreatment	-0.086	0.193***
	(0.08)	(0.04)
Timedummy	-0.033	-0.025
	(0.05)	(0.05)
Timedummy*Dumtreatment	-0.009	0.140**
	(0.11)	(0.06)
Constant	-0.630***	-0.495***
	(0.05)	(0.04)
Log likelihood	-2153.14	-3967.7579
LR chi2	3.34	82.07
Pro>chi2	0.3421	0
Pseudo R2	0.0008	0.0102
No. of observations	3124	5018
Left-censored observations at α2000<=0	2316	3295
Uncensored observations	648	1428
Right-censored observations at α2000>=1	160	295

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Table 5.13 presents the simple DD estimation results for the long-run impact on the portfolio allocation of paying income tax and reduced marginal income tax due to tax reform in tax year 1999-2000. The definition of the control group and the treatment group for each DD estimation can be found in the section 5.5.1.1.1. As we can see, the coefficient of *timedummydumtreatment* is statistically significant in the first model as well in the second model. Both two models have passed the LR Chi-squared test. Hence, if "common trend" holds, the simple DD estimation results suggest that the both paying income tax and the income tax reform in tax year 1999-2000 had a positive impact on the risky asset shares in the long run from 1995 to 2000.

Table 5. 13: The simple DD estimation in tobit for the effect of paying income tax and for the effect of reduced marginal income tax (1995-2005)

	Coefficients for simple DD estimation	
Variables	**DD for the effect of paying income tax**	**DD for the effect of reduced marginal income tax**
Dumtreatment	-0.319***	-0.005
	(0.07)	(0.04)
Timedummy	-0.266***	-0.246***
	(0.05)	(0.04)
Timedummy*Dumtreatment	0.352***	0.242***
	(0.10)	(0.06)
Constant	-0.393***	-0.333***
	(0.04)	(0.03)
Log likelihood	-2574.921	-3884.549
LR chi2	40.72	42.92
Pro>chi2	0	0
Pseudo R2	0.0078	0.0055
No. of observations	3532	4994
Left-censored observations at α2000<=0	2518	3332
Uncensored observations	821	1375
Right-censored observations at α2000>=1	193	287

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

5.6.1.2 Regression-adjusted DD estimation: The effect of paying income tax and the effect of reduced marginal income tax due to the income tax reform in year 1999-2000

To overcome the possible misspecification of the DD estimation, we carry out regression-adjusted DD estimation. We use the DD estimation method to examine the effect of paying income tax on risky asset shares in the short run, which has also been reported as model 1 and model 2 in Table 5.14. The results for the short run impact of the income tax reform on an individual's asset portfolio are reported as model 3 and model 4 in Table 5.14. The results for the long-run impact of paying income tax and long-run impact of reduced marginal income tax due to the tax reform are reported in Table 5.15.

The setting up of model 1 and model 2 has been discussed in section 5.5.1.1.1 and 5.5.1.3. The only difference between model 1 and model 2 is that in model 1 we regress the risky asset share on all variables, while in model 2, we exclude some of the control variables that are found insignificant in model 1.

As we can see in Table 5.14, for model 2 the treatment dummy variable *dumtreatment* is significantly positive; the *timedummy* is significantly negative; the coefficient on the interaction of the treatment and time dummies is negative and significantly different from zero at the 1 percent level. Although the coefficients for these three dummy variables are not statistically significant in model 1, they have the same sign as in model 2. The negative sign for *timedummy* suggests that no matter whether the individual is in the control group or in the treatment group, he/she reduced the proportion of wealth invested in risky assets form 1995 to 2000. The negative sign for *timedummy*dumtreatment* indicates that, after controlling for demographic factors, paying income tax has an negative impact on an individual's risky asset shares. This is a situation where the substitution effect dominates. As we mentioned before, the substitution effect and the wealth effect work together to determine the overall impact on an individual's portfolio allocation. In this case, when the individual starts facing to pay income tax, the return from risky asset would decrease due to the payment of dividend income tax, as a result, the individual's portfolio would be tilted away from the risky asset. This is named as the substitution effect, whereas the wealth effect would have an inverse impact. Paying income tax would induce the individual to hold a relatively aggressive portfolio. Based on the results of model 1 and model 2 in Table 5.14, we suggest that the substitution effect dominates in this case and we find paying income tax would lead to lower risky assets holdings.

In Table 5.14, model 3 and model 4 are used to examine the short-run effect of reduced marginal income tax due to the income tax reform in the tax year 1999-2000. The setup for model 3 and model 4 has been discussed in section 5.5.1.1.1 and 5.5.1.3. The difference between model 3 and model 4 is that in model 3 we regress the risky asset share on all variables, while in model 4, we exclude some of the control variables that are found insignificant in model 3.

As we can in Table 5.14 model 4, after controlling for the demographic factors, the *Dumtreatment* has a positive coefficient of 0.265, which is statistically significant. The coefficient for *Timedummy* is -0.11 and it is also statistically significant, which suggests that keeping other variables unchanged, the average individual's risky asset share fell 11 percentage point during 1995 to 2000. However, the effect of the income tax reform seems not to have an impact on an individual's risky asset shares, because the coefficient on *Timedummy*Dumtreatment* is not statistically different from zero. This null impact has also been found in model 3.

In Table 5.14, we also found that in all four models, most of the control variables have expected sign for their coefficients. For example, it reveals an inversed-U shape impact of net liquid wealth on portfolio allocations. Similar patterns of the impact can be found on the effect of gross housing value and age. Both personal debt and gross labour income have impacts on risky asset shares, and the impacts are positive and statistically significant in model 4.

In conclusion, in the short run from 1995 to 2000, we found a negative and significant impact of paying income tax on risky asset shares, whereas the impact of reduced marginal income tax due to the income tax reform in the tax year 1999-2000 has not been found in this research. In addition, from 1995 to 2000, it seems there was a time trend in holding less risky asset shares.

Now we will look at Table 5.15 which reveals the long-run effect from 1995 to 2005. The four models in Table 5.15 are set up in the similar way as the previous four models in Table 5.14. For model 1 and model 2 in Table 5.15, the control group refers to individuals who did not pay income tax in 1995 and 2005, and treatment group refers to individuals who did not pay income tax in 1995 but paid in 2005. For model 3 and model 4 in Table 5.15, the control group refers to individuals who did not pay income tax in 1995 and 2005, and treatment group refers to individuals who paid income tax in 1995 and 2005.

As we can see from the results of model 1 and model 2 in Table 5.15, in the long run from 1995 to 2005, the negative and significant impact of paying income tax on risky asset shares, which we found in the short-time period (1995-2000), would no longer exist. The results of model 3 and model 4 in Table 5.15 suggests that the reduced marginal income tax due to the income tax reform in tax year 1999-2000 would remain having no impact. Lastly, from 1995 to 2005, it seems the time trend of holding less risky asset shares became more significant.

Table 5. 14: The DD estimation for the effect of paying income tax and for the effect of reduced marginal income tax (1995-2000)

	Coefficients for DD estimation			
	DD for the effect of paying income tax		**DD for the effect of reduced marginal income tax**	
Variables	Model 1	Model 2	Model 3	Model 4
Dumtreatment	0.134*	0.354***	0.036	0.265***
	(0.07)	(0.08)	(0.05)	(0.05)
Timedummy	-0.032	-0.144***	-0.012	-0.110**
	(0.04)	(0.05)	(0.04)	(0.04)
Timedummy*Dumtreatment	-0.136	-0.363***	-0.025	-0.035
	(0.11)	(0.14)	(0.05)	(0.06)
Net liquid wealth	0.882***	2.823***	0.803***	0.917***
	(0.09)	(0.22)	(0.06)	(0.07)
Net liquid wealth squared	-0.197***	-1.337***	-0.148***	-0.101***
	(0.03)	(0.15)	(0.02)	(0.01)
Personaldebt	2.490***	4.690***	1.716***	2.238***
	(0.74)	(0.98)	(0.36)	(0.38)
Housing	0.265***	0.387***	0.232***	0.416***
	(0.04)	(0.05)	(0.03)	(0.04)
Housing squared	-0.026***	-0.040***	-0.035***	-0.055***
	(0.01)	(0.01)	(0.01)	(0.01)
Outstanding mortgage loans	-0.004		0.177***	
	(0.07)		(0.05)	
Gross labour income	0.478	2.212***	-0.004	0.596***
	(0.56)	(0.78)	(0.15)	(0.16)
Incomenlw	0.001***		2.64E-05	
	(1.78E-04)		(1.82E-05)	
Age	0.029***	0.019***	0.029***	0.023***
	(0.01)	(0.01)	(4.76E-03)	(0.01)
Agesquared	-2.25E-04***	-7.38E-05	-2.16E-04***	-1.13E-04**
	(5.33E-05)	(6.06E-05)	(4.52E-05)	(4.91E-05)
Aleveldum	0.041		0.050	
	(0.05)		(0.03)	
Degreedum	-0.005		0.060	
	(0.07)		(0.04)	
Pensiondum	0.056		0.052	
	(0.06)		(0.04)	
Sexdum	0.050	0.055	0.081***	0.078***
	(0.04)	(0.04)	(0.03)	(0.03)
Maritaldum	0.039		0.035	
	(0.04)		(0.03)	
Childdum	-0.025		0.076**	
	(0.06)		(0.03)	

Londondum	-0.055		-0.026	
	(0.06)		(0.04)	
constant	-1.208***	-1.715***	-1.208***	-1.609***
	(0.15)	(0.18)	(0.12)	(0.13)
Log likelihood	-1596.6122	-1836.4184	-2848.0813	-3532.0396
LR chi2	426.91	636.78	606.14	953.50
Pro>chi2	0	0	0	0
Pseudo R2	0.1179	0.1478	0.0962	0.1189
No. of observations	2044	3124	3516	5018
Left-censored observations at α2000<=0	1071	2316	1730	3295
Uncensored observations	828	648	1544	1428
Right-censored observations at α2000>=1	145	160	242	295

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Netliquidwealth, Personaldebt, Housing, Grosslabourincome are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table 5. 15: The DD estimation for the effect of paying income tax and for the effect of reduced income tax (1995-2005)

	Coefficients for DD estimation			
	DD for the effect of paying income tax		**DD for the effect of reduced marginal income tax**	
Variables	Model 1	Model 2	Model 3	Model 4
Dumtreatment	0.045	0.264***	0.130	0.273***
	(0.13)	(0.07)	(0.10)	(0.05)
Timedummy	-0.663***	-0.501***	-0.479***	-0.413***
	(0.14)	(0.05)	(0.11)	(0.05)
Timedummy*Dumtreatment	0.114	-0.010	-0.018	-0.063
	(0.19)	(0.12)	(0.11)	(0.06)
Net liquid wealth	0.748***	1.030***	0.891***	1.010***
	(0.16)	(0.07)	(0.11)	(0.06)
Net liquid wealth squared	-0.097***	-0.124***	-0.117***	-0.127***
	(0.02)	(0.01)	(0.02)	(0.01)
Personaldebt	1.537	2.075***	1.148***	1.572***
	(0.99)	(0.69)	(0.33)	(0.19)
Housing	0.399***	0.296***	0.270***	0.261***
	(0.09)	(0.03)	(0.06)	(0.03)
Housing squared	-0.031**	-0.018***	-0.027***	-0.020***
	(0.01)	(3.68E-03)	(0.01)	(3.40E-03)
Outstanding mortgage loans	-0.087		0.011	
	(0.10)		(0.05)	
Gross labour income	-0.064	0.564	0.038	0.110
	(0.54)	(0.38)	(0.20)	(0.13)
Incomenlw	-7.96E-06		3.99E-05*	
	(3.73E-05)		(2.05E-05)	
Age	0.036***	0.028***	0.034***	0.028***
	(0.01)	(0.01)	(0.01)	(0.01)
Agesquared	-2.64E-04*	-1.58E-04***	-2.37E-04**	-1.76E-04***
	(1.39E-04)	(5.60E-05)	(1.08E-04)	(5.01E-05)
Aleveldum	0.154*		-0.024	
	(0.09)		(0.05)	
Degreedum	0.094		0.099	
	(0.11)		(0.06)	
Pensiondum	0.139		0.027	
	(0.11)		(0.06)	
Sexdum	0.061	0.045	0.089*	0.074**
	(0.09)	(0.04)	(0.05)	(0.03)
Maritaldum	0.048		0.098*	
	(0.10)		(0.05)	
Childdum	-0.054		0.158***	
	(0.10)		(0.05)	

Londondum	0.007		0.077	
	(0.14)		(0.08)	
constant	-1.680***	-1.732***	-1.587***	-1.576***
	(0.33)	(0.18)	(0.25)	(0.15)
Log likelihood	-631.1455	-2238.9498	-1428.5751	-3453.6783
LR chi2	148.72	712.66	284.67	904.66
Pro>chi2	0	0	0	0
Pseudo R2	0.1054	0.1373	0.0906	0.1158
No. of observations	864	3532	1834	4994
Left-censored observations at α2000<=0	571	2518	1096	3332
Uncensored observations	229	821	605	1375
Right-censored observations at α2000>=1	64	193	133	287

*Note: *,**,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Netliquidwealth, Personaldebt, Housing, Grosslabourincome are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

5.6.2 Effect of a capital gain tax cut on an individual's asset allocation

5.6.2.1 Simple DD estimation

Table 5.16 presents the simple DD estimation results for the short-run impact on the portfolio allocation of paying capital gain tax and reduced marginal capital gain tax due to tax reform in tax year 2000-2001. The definition of the control group and treatment group for each DD estimation can be found in section 5.5.1.1.2. As we can see, the coefficient of *timedummydumtreatment* is not statistically significant in the first model and in the second model, which suggests that the effect of paying capital gain tax and capital gain tax reform in tax year 2000-2001 had no impact on risky asset shares in the short run from 1995 to 2000, if the "common trend" assumption holds. However, normally the common trend would not hold and we have to augment this simple DD estimation with regression-adjusted DD estimation by controlling for relevant and observable factors. We will look at the augmented estimation later in section 5.6.2.2.

Table 5. 16: The simple DD estimation in tobit for the effect of paying capital gain tax and for the effect of reduced marginal capital gain tax (1995-2000)

	Coefficients for simple DD estimation	
Variables	**DD for the effect of paying capital gain tax**	**DD for the effect of reduced marginal capital gain tax**
Dumtreatment	0.916***	1.275***
	(0.19)	(0.21)
Timedummy	0.035	0.035
	(0.03)	(0.03)
Timedummy*Dumtreatment	0.368	0.023
	(0.26)	(0.30)
Constant	-0.455***	-0.456***
	(0.02)	(0.02)
Log likelihood	-5951.1805	-5935.9163
LR chi2	76.60	75.16
Pro>chi2	0	0
Pseudo R2	0.0064	0.0063
No. of observations	7822	7808
Left-censored observations at α2000<=0	5329	5324
Uncensored observations	2063	2056
Right-censored observations at α2000>=1	430	428

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Table 5.17 presents the simple DD estimation results for the long-run impact on the portfolio allocation of paying capital gain tax and reduced marginal capital gain tax due to tax reform in tax year 2000-2001. The definition of the control group and treatment group for each DD estimation can be found in section 5.5.1.1.2. As we can see, the coefficient of *timedummydumtreatment* is statistically significant in the first model but not in the second model. Both models have past Chi-squared test. Hence, if "common trend" holds, the simple DD estimation results suggest that paying the capital gain tax had a positive impact on risky asset shares in the long run from 1995 to 2000, but the reduced marginal capital gain tax due to the income tax reform in tax year 1999-2000 had no impact in the long run.

Table 5. 17: The simple DD estimation in tobit for the effect of paying capital gain tax and for the effect of reduced marginal capital gain tax (1995-2005)

	Coefficients for simple DD estimation	
Variables	**DD for the effect of paying capital gain tax**	**DD for the effect of reduced marginal capital gain tax**
Dumtreatment	0.457***	1.304***
	(0.08)	(0.08)
Timedummy	-0.084***	-0.081***
	(0.03)	(0.03)
Timedummy*Dumtreatmen t	1.055***	0.170
	(0.11)	(0.11)
Constant	-0.595***	-0.560***
	(0.03)	(0.03)
Log likelihood	-3958.8997	-3928.6518
LR chi2	414.52	651.47
Pro>chi2	0	0
Pseudo R2	0.0497	0.0766
No. of observations	5978	5948
Left-censored observations at α2000<=0	4370	4292
Uncensored observations	1263	1312
Right-censored observations at α2000>=1	345	344

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

5.6.2.2 Regression-adjusted DD estimation: The effect of paying capital gains tax and the effect of reduced marginal capital gain tax due to the tax reform in tax year 2000-2001

Similar to what we did in section 5.6.1.2, in order to overcome the possible misspecification of the DD estimation, we carry out regression-adjusted DD estimation for the effect of the capital gains tax. The results for the short-run impact of paying capital gains tax on individual's asset portfolio are reported as model 1 and model 2 in Table 5.18. The short-run effects of the reduced marginal capital gains tax due to the tax reform in tax year 2000-2001 are also presented as model 3 and model 4 in Table 5.18. Table 5.19 reveals the long-run impact of capital gains tax from 1995 to 2005.

The set up of model 1 and model 2 in Table 5.18 is similar to the set up of model 1 and model 2 in Table 5.14, except that in Table 5.18 we look at the capital gains tax instead of income tax. The set up for model 1 and model 2 is discussed in section 5.5.1.1.2 and 5.5.1.3. In model 1 we regress the risky asset share on all variables, while in model 2, we exclude some of the control variables that are found to be insignificant in model 1.

As we can see from Table 5.18, the coefficients for *timedummy*dumtreatment* in model 1 and model 2 are both equal to 0.296 and statistically insignificant. This suggests that paying capital gains tax has no impact on an individual's risky asset share in the short run from 1995 to 2000. This could be a situation where the substitution effect and the wealth effect fully offset each other. The substitution effect, in this case, is a negative impact of paying capital gains tax on risky asset shares. When an individual starts paying capital gains tax, the return from the risky asset would decrease, hence the individual's portfolio would be tilted away from the risky asset. On the contrary, the wealth has a positive effect. Paying the capital gains tax would prod the individual to hold a relatively aggressive portfolio. Based on the results of model 1and model 2 in Table 5.18, we may conclude that the substitution effect is fully offset by the wealth effect and paying the capital gains tax would not have an impact on risky assets shares in the short run.

In Table 5.18, the coefficients for *dumtreatment* in model 1 and model 2 are also not statistically significant which implies that after control for the demographic factors the average risky asset shares held by individuals in the treatment group was more or less the same as the average risky asset shares held by individuals in the control group. Furthermore, if we look at the results of model 2 in Table 5.18, we find that the coefficient for *timedummy* has a negative sign and is significantly different from zero at the 1 percentage level in model 2, although it is statistically insignificant in model 1. This negative coefficient for *timedummy* suggests that no matter whether the individual is in the control group or in the treatment group, he/she would like to cut his/her risky asset shares from 1995 to 2000.

In Table 5.18, model 3 and model 4 are used to examine the short-run effect of a reduced marginal capital gain tax due to the tax reform in the tax year 2000-2001.The set up for model 3 and model 4 is presented in section 5.5.1.1.2 and 5.5.1.3. Again, the difference between model 3 and model 4 is that in model 3 we regress the risky asset share on all variables, while in model 4, we exclude some of the control variables that are found to be insignificant in model 3.

As we can in Table 5.18 model 4, after controlling for the demographic factors, the *Dumtreatment* has a negative coefficient of -1.041, which is statistically significant. The coefficient for *Timedummy* is -0.122 and it is also statistically significant, which suggests that keeping other variables unchanged, the average individual's risky asset share fell 12 percentage point during 1995 to 2000. However, the effect of the capital gain tax reform seems not to have an impact on individual's risky asset shares, because the coefficient for *Timedummy*Dumtreatment* is not statistically different from zero. This no impact has also been found in model 3.

In Table 5.18, we also found that in all four models, most of the control variables have the expected sign for their coefficients. For example, it reveals an inversed-U shape impact of net liquid wealth on portfolio allocations. Similar patterns of the impact can be found on the effect of gross house value and age. Both personal debt and gross labour income have impacts on risky asset shares, and the impacts are positive and statistically significant in model 4.

In conclusion, by using the DD estimation method, in the short run from 1995 to 2000, we did not find an impact of paying the capital gains tax on risky asset shares. Similarly, the impact of the reduced marginal capital gains tax due to the tax reform in tax year 2000-2001 has also not been found in this research. In addition, from 1995 to 2000, it seems there was a time trend in holding less risky asset shares.

Finally we will look at Table 5.19 which reveals the long-run effect from 1995 to 2005. The four models in Table 5.19 are set up in the similar way as the previous four models in Table 5.18. For model 1 and model 2 in Table 5.10, the control group refers to individuals who did not pay capital gain tax in 1995 and 2005, and the treatment group refers to individuals who did not pay capital gains tax in 1995 but paid in 2005. For model 3 and model 4 in Table 5.19, the control group refers to individuals who did not pay capital gains tax in 1995 and 2005, and the treatment group refers to individuals who paid capital gains tax in 1995 and 2005.

As we can see from the results of model 1 and model 2 in Table 5.19, in the long run from 1995 to 2005, there is a positive and significant impact of the paying capital gains tax on risky asset shares, which we did not find in the short time period (1995-2000) in Table 5.18. The possible reason is that capital gains are significantly bigger in the long run than in the short run. Hence the tax change is more important in the long run than in the short run. In comparison, labour income is steadier over the year, so the income tax change is more likely to have an impact in the short run than in the long run. That could be the reason why we find negative impact of paying income tax in the short run in the previous section 5.6.1.2.

In contrast, the results of model 3 and model 4 in Table 5.19 suggests that the reduced marginal capital gain tax due to the tax reform in tax year 2000-2001 would have no impact. Lastly, from 1995 to 2005, it seems the time trend is that the average proportion of wealth invested in risky assets was dramatically reduced.

Table 5. 18: The DD estimation for the effect of paying capital gain tax and for the effect of reduced marginal capital gain tax (1995-2000)

	Coefficents for DD estimation			
	DD for the effect of paying capital gain tax		DD for the effect of reduced marginal capital gain tax	
Variables	Model 1	Model 2	Model3	Model 4
Dumtreatment	0.084	-0.024	-0.307	-1.041***
	(0.14)	(0.17)	(0.19)	(0.24)
Timedummy	0.002	-0.108***	-0.010	-0.122***
	(0.02)	(0.02)	(0.03)	(0.03)
Timedummy*Dumtreatment	0.296	0.296	-0.023	-0.101
	(0.22)	(0.26)	(0.23)	(0.28)
Net liquid wealth	1.496***	2.404***	0.704***	1.323***
	(0.11)	(0.12)	(0.07)	(0.08)
Net liquid wealth squared	-0.730***	-1.049***	-0.067***	-0.134***
	(0.07)	(0.08)	(0.01)	(0.01)
Personaldebt	2.229***	4.228***	1.254***	2.871***
	(0.36)	(0.38)	(0.34)	(0.36)
Housing	0.190***	0.359***	0.247***	0.468***
	(0.03)	(0.03)	(0.04)	(0.04)
Housing squared	-0.032***	-0.053***	-0.041***	-0.081***
	(0.01)	(0.01)	(0.01)	(0.01)
Outstanding mortgage loans	0.159***		0.117**	
	(0.04)		(0.05)	
Gross labour income	-0.044	0.781***	0.045	0.914***
	(0.14)	(0.12)	(0.14)	(0.12)
Incomenlw	3.49E-05*		3.27E-05*	
	(1.83E-05)		(1.86E-05)	
Age	0.026***	0.022***	0.028***	0.023***
	(4.28E-03)	(3.83E-03)	(4.36E-03)	(3.90E-03)
Agesquared	-2.04E-04***	-1.64E-04***	-2.17E-04***	-1.60E-04***
	(4.17E-05)	(3.84E-05)	(4.26E-05)	(3.92E-05)
Aleveldum	0.037		0.054*	
	(0.03)		(0.03)	
Degreedum	0.064		0.090**	
	(0.04)		(0.04)	
Pensiondum	0.069**		0.056*	
	(0.03)		(0.03)	
Sexdum	0.078***	0.046*	0.084***	0.055**
	(0.02)	(0.02)	(0.03)	(0.03)
Maritaldum	0.020		0.028	
	(0.03)		(0.03)	
Childdum	0.078**		0.079**	
	(0.03)		(0.03)	

Londondum	-0.021		-0.033	
	(0.04)		(0.04)	
constant	-1.103***	-1.385***	-1.172***	-1.469***
	(0.10)	(0.09)	(0.10)	(0.09)
Log likelihood	-3393.1970	-5283.3130	-3426.4464	-5354.3677
LR chi2	667.07	1412.34	576.43	1238.25
Pro>chi2	0	0	0	0
Pseudo R2	0.0895	0.1179	0.0776	0.1036
No. of observations	4200	7822	4188	7808
Left-censored observations at α2000<=0	2150	5329	2145	5324
Uncensored observations	1756	2063	1751	2056
Right-censored observations at α2000>=1	294	430	292	428

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Netliquidwealth, Personaldebt, Housing, Grosslabourincome are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

Table 5. 19: The DD estimation for the effect of paying capital gain tax and for the effect of reduced marginal capital gain tax (1995-2005)

	Coefficents for DD estimation			
	DD for the effect of paying capital gain tax		**DD for the effect of reduced marginal capital gain tax**	
Variables	Model 1	Model 2	Model 3	Model 4
Dumtreatment	0.187	0.266***	0.710***	0.956***
	(0.12)	(0.08)	(0.16)	(0.09)
Timedummy	-0.471***	-0.425***	-0.479***	-0.413***
	(0.07)	(0.04)	(0.07)	(0.04)
Timedummy*Dumtreatment	0.721***	0.813***	0.247	0.172
	(0.17)	(0.12)	(0.18)	(0.11)
Net liquid wealth	1.208***	1.094***	0.683***	0.151*
	(0.34)	(0.18)	(0.26)	(0.08)
Net liquid wealth squared	-0.787***	-0.536***	-0.316***	-0.030**
	(0.23)	(0.10)	(0.11)	(0.01)
Personaldebt	2.427***	2.372***	1.641***	0.567**
	(0.66)	(0.38)	(0.60)	(0.22)
Housing	0.293***	0.259***	0.296***	0.266***
	(0.07)	(0.03)	(0.07)	(0.03)
Housing squared	-0.027***	-0.017***	-0.025***	-0.018***
	(0.01)	(3.87E-03)	(0.01)	(3.61E-03)
Outstanding mortgage loans	-0.027		-0.021	
	(0.04)		(0.04)	
Gross labour income	-0.132	0.383***	-0.120	0.431***
	(0.20)	(0.12)	(0.20)	(0.11)
Incomenlw	2.38E-05		2.29E-05	
	(2.12E-05)		(2.09E-05)	
Age	0.027***	0.027***	0.028***	0.025***
	(0.01)	(0.01)	(0.01)	(4.87E-03)
Agesquared	-2.01E-04*	-2.23E-04***	-2.03E-04*	-1.97E-04***
	(1.18E-04)	(5.08E-05)	(1.12E-04)	(4.82E-05)
Aleveldum	-0.029		-0.026	
	(0.05)		(0.05)	
Degreedum	0.007		0.014	
	(0.07)		(0.07)	
Pensiondum	0.129**		0.132**	
	(0.05)		(0.05)	
Sexdum	0.046	0.045	0.045	0.047
	(0.05)	(0.03)	(0.05)	(0.03)
Maritaldum	0.044		0.057	
	(0.06)		(0.06)	
Childdum	0.087*		0.079	
	(0.05)		(0.05)	

Londondum	0.068		0.034	
	(0.08)		(0.09)	
constant	-1.427***	-1.485***	-1.429***	-1.399***
	(0.21)	(0.12)	(0.21)	(0.12)
Log likelihood	-1668.6700	-3790.9707	-1624.1943	-3779.1636
LR chi2	272.03	750.38	300.02	950.44
Pro>chi2	0	0	0	0
Pseudo R2	0.0754	0.0901	0.0845	0.1117
No. of observations	2296	5978	2246	5948
Left-censored observations at α2000<=0	1535	4370	1499	4292
Uncensored observations	601	1263	589	1312
Right-censored observations at α2000>=1	160	345	158	344

Note:

,,*** coefficient significantly different from zero at the 10%,5%, and 1% level, respectively.*

Netliquidwealth, Personaldebt, Housing, Grosslabourincome are measured in £1,000 in the above regression, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £1,000 respectively.

5.6.3 Standard Tobit estimation with additional variable of marginal tax rate

Table 5.20 shows the coefficients and standard errors on each explanatory variable for the Tobit estimation specified in section 5.5.2 of this chapter. As we can see, an increase in the marginal tax rate would lead to an increase in the proportion of wealth invested in risky assets, while this effect is not statistically significant from zero. The possible explanation for this positive correlation between the marginal tax rate and portfolio share in risky assets would be as follows. An increased marginal tax rate on ordinary income would reduce households' dispensable income. Because of habit persistence in consumption, households tend to find alternative means to make up those losses and keep their habit level of consumption. One possible way is to shift their portfolio towards risky assets and away from risk-free assets. Investment in common stocks would not only generate dividends which are taxed on ordinary income tax rate, but also generate capital gains. UK residents have "an annual tax-free allowance for each year and they only pay tax on total net gains above this amount, using the Capital Gains Tax rate for that tax year"(HMRC). Hence, it is reasonable and possible for household to invest in risky assets and earn tax-free capital gains.

Table 5.20 also presents the results for the effect of previous portfolio choice, net liquid wealth, personal debt, gross housing value, gross labour income, age and gender. It shows that the portfolio share invested in risky assets is increasing with the previous portfolio share in investment (α_{1995}), net liquid wealth (*Netliquidwealth*) if it is below £1,713,235, personal debt (*Personaldebt*), gross housing value (*Housing*) if it is below £358,079, gross labour income (*Grosslabourincome*), age (*Age*) if age is under 62 and being male. The portfolio share is decreasing with net liquid wealth (*Netliquidwealth*) if it is above £1,713,235, gross housing value (HOUSING) if it is above £358,079, and age (*Age*) if age is above 62. All coefficients in the regression, except for the ones on *Marginaltaxrate2000* and *Sexdum*, are either significantly different from zero at the 5 percent significant level. Furthermore, the model is also very significant because the p-value is approximately zero on the chi-squared statistics.

Table 5.20 reveals an inversed-U shape impact of net liquid wealth on portfolio allocation. Keeping all the other factors constant, individuals with higher net liquid wealth are less risk averse and therefore allocate a higher proportion of their wealth to risky assets. In this case, cross-sectional variation in portfolio allocation is due to a different level of risk aversion that is influenced by different level of wealth. This positive relationship between portfolio share and wealth is also found in the analysis of Wachter and Yogo (2010).

The positive influence of personal debt on risky asset shares suggests that the financial sophistication of the household is a determinant of the extent to which they invest in risky assets.

Gross house value can also affect individuals' risk attitude and hence influence their asset allocation decisions. In our dataset, nearly 96 percent of the respondents were living in a property that worth less than the threshold of £358,079. As their gross housing value rise up, their risky asset shares increase at a decreasing rate. Investors may regard housing as a financial asset that act as insurance. It will encourage investors to take a more risky position. Only when the gross house value is over the threshold, the negative house price risk and the negative housing consumption-commitment effect[40] would overwhelm the positive housing wealth effect. And then the household would invest less in risky assets.

The age effect is a bit complicated. It has an invsered-U shape relationship with investment in risky assets. The positive relationship between age and risky asset share could be explained by risk aversion or through habit. In other words, as individuals age their habit level of consumption does not grow as quickly as their income and hence risk aversion declines. Also as people age they face different sorts of risks, for example, they may get ill and this health reason cause people to be more risk-averse. The combination of these two effects may explain the inversed-U shape effect of age. Furthermore, this hump-shaped pattern in age is also consistent with findings in Ameriks and Zeldes (2004) and Wachter and Yogo (2010).

The gross annual labour income has a positive impact on risky asset shares, as we can see in Table 5.20, and the coefficient of *Grosslabourincome* is statistically significant. The individual's risk attitude could vary with the gross labour income level. A Higher level of gross labour income could encourage individual to take higher risk in investment.

[40] For the details of these effects, please refer to Literature chapter 2.7.1

Table 5. 20: Results for Tobit estimation with additional variable of marginal tax rate

Variables	Coefficient	Standard Error
α1995	0.732***	(0.05)
Marginal tax rate 2000	0.187***	(0.25)
Net liquid wealth	0.466***	(0.05)
Net liquid wealth squared	-0.014***	(6.05E-03)
Personaldebt	1.370***	(0.4)
Housing	0.164***	(0.02)
Housing squared	-0.023	(0.02)
Gross labour income	0.474**	(0.2)
Age	0.025***	(0.01)
Agesquared	-2.02E-04***	(5.13E-05)
Sexdum	0.019	(0.03)
Constant	-1.469***	(0.14)
Log likelihood	-2613.942	
LR chi2 (11)	813.86	
Pro>chi2	0	
Pseudo R2	0.1347	
No. of observations	3762	
Left-censored observations at α2000<=0	2439	
Uncensored observations	1101	
Right-censored observations at α2000>=1	222	

Note:

,,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table 5.21 reports the marginal effects in the above Tobit regression model for 2000. The results show the Tobit marginal effect of one unit increase in the average marginal tax rate on the expected portfolio shares in risky assets. An increase of ten percentage point in the marginal tax rate on interest and dividend income could boost the proportion of net wealth invested in risky assets by 0.54 percentage in point. In other words, the expected/predicted portfolio share would increase from 15percent to 15.54 percentage. This 15 percentage of predicted portfolio share is not presented in the following Table 5.21. It is part of the results we obtain when estimating the marginal effects after Tobit. If we increase 15 percentage by 0.54 percentage point, we get 15.64 percent. However, since we did not find a marginal tax rate effect in Table 5.20, and the marginal effect of income tax on risky asset shares is statistically insignificant based on the results in Table 5.21, we need to interpret these results with caution.

Table 5. 21: Marginal effect of income taxation on risky asset shares

Variables	dy/dx		Standard error	X
α1995	0.212	***	(0.01)	0.17
Marginal tax rate 2000	0.054		(0.07)	0.125
Net liquid wealth	0.149	***	(0.04)	0.071
Net liquid wealth squared	-3.94E-03	***	(9.10E-04)	0.121
Personaldebt	0. 413	***	(0.15)	0.015
Housing	0.047	***	(0.01)	0.783
Housing squared	-6.62E-03		(0.01)	0.483
Gross labour income	0.112	**	(0.06)	0.102
Age	0.007	***	(1.42E-03)	47.75
Agesquared	-5.85E-05	***	(1.10E-05)	2127.44
Sexdum[(a)]	0.005			0.441
No. of observations		3762		
left-censored observations at α2000<=0		2439		
uncensored observations		1101		
right-censored observations at α2000>=1		222		

*Note: *,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Outstandingmortgage are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

[(a):] dy/dx is for discrete change of dummy variable from 0 to 1.

The following Table 5.22 is set up for testing the robustness of our previous results that marginal tax rate has no impact on risky asset holdings. By running these additional specifications, we still do not find the impact of marginal tax rate on risky asset holdings.

In model 1 of Table 5.22, we still follow Poterba and Samwick'(2003) approach to calculate the marginal tax rate for each individuals in 2000, and we regress on all the regressors including variables on the number of children aged below 15 in the family (numberofkids) and variables on the health of the individual (*youngunhealthdum, oldhealthdum, oldunhealthdum, healthstatus*). The marginal effects after Tobit regression are also reported in Table 5.22. The marginal effects measure the expected change in risky asset share as a function of one unit increase in the explanatory variable. The second column presents the value of dy/dx and the third column presents the average value of the explanatory variable.

As we can see in model 1, previous risky asset share (*α1995*) has a positive impact on risky asset holdings in 2000. In addition, the second column suggests that an increase of ten percentage point in previous risky asset share (*α1995*) implies an increase in the proportion of net wealth invested in risky assets by 2.46 percentage point in 2000. In other words, the expected/predicted portfolio share would increase from 25.95 percent[41] to 28.41 percent. The net liquid wealth has an inverse U-shape of impact. If average net liquid wealth increases by £100,000, the expected/predicted risky asset share would increase by 20.9 percentage point. Personal debt has a positive impact. An increase of £100,000in personal debt would result in an increase of 60.2 percentage point in

[41] Please note this predicted portfolio share is not presented in the Table 5.13. It is part of the results we obtain when estimating the marginal effects after Tobit

expected risky asset share. Gross house value has an inverse U-shape of impact. An increase of £100,000 in gross house value would result in an increase of 4.9 percentage point in expected risky asset share. Outstanding mortgage has a positive impact. If the average outstanding mortgage increases by £100,000, the expected portfolio share in risky asset would increase by 5.4 percentage point. The impact of *incomenlw* on risky asset holdings is positive, and the marginal effect of *incomenlw* is close to zero. Age has an inverse U-shape of impact. An increase of 10 years in average age would increase the expected risky asset share by 16.36 percentage point. Because the marginal effect of the dummy variables is measured in terms of discrete change of dummy variable from 0 to 1, the results in Table 5.22 suggest that an individual whose highest education level is first degree or higher would invest 3.9 percentage point higher than an individual with whose highest education is an O-level or under. Compared with the retirees' risky asset share, the risky asset share of employees is 5 percentage point less; the risky asset share of self-employed people is 7.8 percentage point less; the risky asset share of unemployed people is 8.9 percentage point less. The presence of chid/children increases the risky asset share by 7.5 percentage point. Compared with individuals who are young and have good health, individuals who are old and unhealthy would invest 14.2 percentage point less in risky asset share.

In order to test the robustness of our results, we also regress on lagged marginal income tax rate in 1999 and report the results in model 2 of the following Table 5.22. As we can see, the impact of marginal tax rate on risky asset holdings still has not been found in model 2. The effects of other regressors are similar to what we find in model 1.

We recognise that some of the explanatory variables are potentially endogenous, and this could lead to inconsistent estimators. Therefore, we carry out a two-step procedure (Wooldridge, 2002, p532) to test the exogeneity, and we find that there is evidence that *grosslabourincome* and *incomenlw* are endogenous in the specification. Hence, we regress on *permanent income*[42] and *permanentincomenlw* to test the robustness of our results, and we present the results in the model 3 of the following Table 5.22. For comparison, we also regress on *gross labour income* and *incomenlw* in model 4 using the same sample data as in model 3.

As we can see, in terms of sign and significance level, there is no much difference between model 3 and model 4 except that in model 3 the coefficients of *Degreedum* and *Sexdum* are not statistically significant.

In conclusion, the impact of marginal tax rate on risky asset holdings has not been found from model 1 to model 4, which shows the robustness of the results.

[42] The way we construct Permanentincome and *Permanentincomenlw* is similar to the way we construct them in Chapter 3. We follow Guariglia's (2001) approach to obtain the value of permanent income for individuals whose age is between 21 and 65. We use the BHPS data in 1995 and 2000, and we, firstly, run a random effect model by regressing individuals' gross labour income on "age, age squared, education dummies, occupational dummies, and interactions of the latter two groups of dummies with age and age squared" (Guariglia, 2001, p627). Then we use the estimated coefficients to predict the permanent income for individuals in 1995 and 2000 respectively. Finally, we divide permanent income by net liquid wealth to get the ratio. The reason why we regress on Permanentincome and *Permanentincomenlw* is that we recognise gross labour income is potentially endogenous which may lead to inconsistent estimators.

Table 5. 22: Robustness tests for the null effect of marginal tax rate on risky asset holdings in 2000

Variables	Model 1	Marginal effect for model 1 dy/dx	X	Model 2 regress on mtr1999	Model 3 regress on Pincome, Pincomenlw	Model 4 compare with model 3
Allocation1995	0.491***	0.246***	0.278	0.493***	0.444***	0.442***
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Marginal tax rate 2000	-0.230	-0.115	0.130		-0.204	-0.162
	(0.26)	(0.13)			(0.19)	(0.27)
Lagged marginal tax rate				-0.234		
				(0.20)		
Netliquidwealth	0.526***	0.264***	0.134	0.521***	0.587***	0.589***
	(0.08)	(0.04)		(0.08)	(0.09)	(0.09)
Netliquidwealthsquared	-0.109***	-0.055***	0.143	-0.107***	-0.122***	-0.123***
	(0.02)	(0.01)		(0.02)	(0.03)	(0.03)
Personaldebt	1.202***	0.602***	0.015	1.126***	1.209***	1.191***
	(0.33)	(0.17)		(0.33)	(0.33)	(0.33)
Housing	0.121***	0.060***	0.997	0.136***	0.054	0.061
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Housingsquared	-0.021***	-0.011***	1.844	-0.022***	-0.011	-0.012
	(0.01)	(3.95E-03)		(0.01)	(0.01)	(0.01)
Outstandingmortgage	0.107***	0.054***	0.251	0.102**	0.132***	0.134***
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Grosslabourincome	0.077	0.039	0.112	0.062		0.037
	(0.19)	(0.10)		(0.16)		(0.19)
Incomenlw	1.10E-04***	5.51E-05***	28.482	1.11E-04***		1.04E-04***
	(4.03E-05)	(2.00E-05)		(4.01E-05)		(3.99E-05)

Permanentincome					0.678	
					(0.41)	
Permanentincomenlw					8.14E-05***	
					(2.88E-05)	
Age	0.036***	0.018***	49.988	0.035***	0.033**	0.044***
	(0.01)	(3.33E-03)		(0.01)	(0.01)	(0.01)
Agesquared	-3.28E-04***	-1.64E-04***	2806.470	-3.27E-04***	-2.81E-04*	-4.27E-04***
	(7.05E-05)	(4.00E-05)		(7.21E-05)	(1.62E-04)	(1.40E-04)
Aleveldum	0.044	0.022	0.272	0.052	-0.002	0.033
	(0.03)	(0.02)		(0.04)	(0.04)	(0.04)
Degreedum	0.076*	0.039*	0.150	0.072	0.011	0.078*
	(0.04)	(0.02)		(0.05)	(0.06)	(0.05)
Pensiondum	0.039	0.020	0.473	0.029	0.030	0.023
	(0.04)	(0.02)		(0.04)	(0.04)	(0.04)
Employeedum	-0.069	-0.035	0.609	-0.076	-0.070	-0.083
	(0.07)	(0.03)		(0.06)	(0.08)	(0.08)
Selfemployeddum	-0.169**	-0.078***	0.076	-0.168**	-0.178**	-0.161*
	(0.07)	(0.03)		(0.07)	(0.08)	(0.08)
Unemployeddum	-0.195**	-0.089***	0.047	-0.182**	-0.235**	-0.235**
	(0.08)	(0.03)		(0.09)	(0.10)	(0.10)
Sexdum	0.033	0.016	0.497	0.021	0.054	0.059*
	(0.03)	(0.01)		(0.03)	(0.03)	(0.03)
Maritaldum	-0.009	-0.004	0.619	-0.013	0.007	0.002
	(0.03)	(0.02)		(0.03)	(0.04)	(0.04)
Childdum	0.145**	0.075**	0.200	0.178***	0.130**	0.134**
	(0.06)	(0.03)		(0.07)	(0.06)	(0.06)
Numberofkids	-0.043	-0.021	0.431	-0.051	-0.047	-0.047
	(0.03)	(0.02)		(0.03)	(0.03)	(0.03)

Londondum	-0.018	-0.009	0.097	-0.022	0.013	0.009
	(0.05)	(0.02)		(0.05)	(0.05)	(0.05)
Youngunhealthdum	0.007	0.003	0.012	0.042		
	(0.14)	(0.07)		(0.15)		
Oldhealthdum	0.050	0.025	0.170	0.057		
	(0.07)	(0.04)		(0.08)		
Oldunhealthdum	-0.349	-0.142**	0.006	-0.349		
	(0.23)	(0.07)		(0.23)		
Healthstatus	-0.003	-0.001	2.161	-0.001	-0.003	-0.002
	(0.02)	(0.01)		(0.02)	(0.02)	(0.02)
Constant	-1.089***			-1.062***	-1.057***	-1.204***
	(0.16)			(0.17)	(0.24)	(0.23)
Log likelihood	-1745.65			-1646.49	-1348.41	-1349.46
LR chi2	516.30			488.89	386.27	384.15
Pro>chi2	0			0	0	0
Pseudo R2	0.1288			0.1293	0.1253	0.1246
No. of observations	2203			2074	1708	1708
left-censored observations at α2000<=0	957			897	737	737
uncensored observations	1072			1010	846	846
right-censored observations at α2000>=1	174			167	125	125

Note:,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing, Outstandingmortgage,Grosslabourincome, and Permanentincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

5.7 Conclusion

In conclusion, this chapter has explored and examined the impact of taxation on portfolio shares in risky assets. We considered how taxation can impact on the individual's desire to take on risk. We use individual level data from the British Household Panel Survey (BHPS) for 1995, 2000 and 2005. We used simple DD estimations first to examine the impact of taxation. We then augment the simple model with Regression-adjusted DD estimation by controlling for relevant demographic factors and we have found that in the short run paying income tax has a negative impact on risky asset shares, but this effect has not been found in the long run from 1995 to 2005. In addition, the reduced marginal income tax due to the income tax reforms in the tax year 1999-2000 may not have an impact on risky asset shares both in the short run and in the long run. Although we have not found any significant impact of paying capital gain tax on risky asset shares in the short run, we have found a significantly positive impact of paying capital gain tax in the long run from 1995 to 2005. Furthermore, we have not found any significant effect on risky asset shares from a fall in the marginal capital gains tax rate in the tax year 2000-2001, neither in the short run or in the long run. Finally, we found the time trend in risky asset shares is falling overtime.

Additionally, we then estimate a standard Tobit regression for 2000 to examine the marginal tax rate effect on the portfolio share in risky asset. The marginal tax rate on ordinary saving and investment income for each respondent in the corresponding BHPS survey is calculated using the method introduced by Poterba and Samwick (2003). By controlling for a series of socioeconomic and demographic variables, we find a positive relationship between the marginal tax rate and the proportion of wealth invested in risky assets, but that this effect is not statistically significant from zero.

The main results we obtain are robust to using a heteroscedastic Tobit estimator and for the CQR model. The robustness tests for the first result (the negative impact of paying income tax in the short run) are presented in Table (A) of Appendix. The robustness tests for the second result (the positive impact of paying capital gain tax in the long run) are presented in Table (B) of Appendix. The robustness tests for the third result (no impact of marginal income tax rate) are presented in Table (C) of Appendix.

The policy implication of this research can be found in the following conclusion chapter 6.2.2.

Appendix:

Table (A): robustness tests for the negative impact of paying income tax in the short run

Variables	Tobit	Heteroscedastic Tobit		Quantile 0.6	Quantile 0.8
		coefficient	γ		
Dumtreatment	0.354***	0.221*	0.43**	0.031	0.150**
	(0.08)	(0.12)	(0.20)	(0.02)	(0.06)
Timedummy	-0.144***	-0.233***	0.314***	-0.021	-0.028
	(0.05)	(0.06)	(0.12)	(0.01)	(0.04)
Timedummy*Dumtreatment	-0.363***	-0.258*	-0.448*	-0.228***	-0.480***
	(0.14)	(0.15)	(0.26)	(0.04)	(0.13)
Net liquid wealth	2.823***	3.717***	-4.084***	2.001***	2.531***
	(0.22)	(0.34)	(0.52)	(0.05)	(0.17)
Net liquid wealth squared	-1.337***	-2.892***	3.082***	-0.979***	-1.352***
	(0.15)	(0.42)	(0.44)	(0.04)	(0.18)
Personaldebt	4.690***	4.331**	1.945	1.991***	3.454***
	(0.98)	(2.02)	(3.37)	(0.30)	(0.67)
Housing	0.387***	0.535***	-0.172	0.016	0.132***
	(0.05)	(0.09)	(0.13)	(0.01)	(0.04)
Housing squared	-0.040***	-0.092***	0.043	0.002	-0.009
	(0.01)	(0.03)	(0.03)	(1.54E-03)	(0.01)
Gross labour income	2.212***	3.25***	-2.076	1.212***	2.406***
	(0.78)	(0.95)	(1.72)	(0.21)	(0.67)
Age	0.019***	0.044***	-0.031	0.004**	0.007
	(0.01)	(0.01)	(1.72)	(2.12E-03)	(4.97E-03)
Agesquared	-7.38E-05	2.76E-04	2.40E-04*	-4.44E-05**	-3.39E-05
	(6.06E-05)	(2.11E-04)	(1.45E-04)	(1.95E-05)	(4.47E-05)
Sexdum	0.055	0.005	0.123	0.020	0.014
	(0.04)	(0.05)	(0.10)	(0.01)	(0.03)
constant	-1.715***	-2.485***		-0.162***	-0.331**
	(0.18)	(0.34)		(0.06)	(0.15)
Pseudo R2	0.1478			0.1990	0.1942
No. of observations	3124	3124		844	1813
log likelihood	-1836.42	-1774.00			

Note: **,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table (B): robustness tests for the positive impact of paying capital gain tax in the long run

Variables	Tobit	Heteroscedastic Tobit coefficient	$\boxed{\gamma}$	Quantile 0.6	Quantile 0.8
Dumtreatment	0.266***	0.173***	-0.098	0.085***	0.325***
	(0.08)	(0.06)	(0.18)	(0.01)	(0.04)
Timedummy	-0.425***	-0.39***	0.214*	-0.027***	-0.249***
	(0.04)	(0.06)	(0.11)	(0.01)	(0.03)
Timedummy*Dumtreatment	0.813***	0.673***	0.392	0.796***	0.552***
	(0.12)	(0.08)	(0.26)	(0.01)	(0.06)
Net liquid wealth	1.094***	1.862***	-7.835***	0.109***	0.298***
	(0.18)	(0.19)	(0.64)	(0.01)	(0.07)
Net liquid wealth squared	-0.536***	-1.684***	5.023***	-0.103***	-0.245***
	(0.10)	(0.25)	(0.55)	(0.01)	(0.04)
Personaldebt	2.372***	1.226**	-3.205**	0.208***	1.681***
	(0.38)	(0.64)	(1.33)	(0.03)	(0.19)
Housing	0.259***	0.313***	-0.101	0.004	0.125***
	(0.03)	(0.05)	(0.09)	(3.13E-03)	(0.02)
Housing squared	-0.017***	-0.039***	0.03**	0.002***	-0.003
	(3.87E-03)	(0.01)	(0.01)	(3.33E-04)	(1.88E-03)
Grosslabourincome	0.383***	0.282***	-0.074	0.021**	0.292***
	(0.12)	(0.09)	(0.27)	(0.01)	(0.06)
Age	0.027***	0.022***	0.001	0.002**	0.012***
	(0.01)	(0.01)	(0.01)	(7.81E-04)	(3.67E-03)
Agesquared	-2.23E-04***	1.65E-04***	4.06E-05***	-1.69E-05**	-1.10E-04***

	(5.08E-05)	(3.98E-05)	(1.21E-05)	(7.73E-06)	(3.80E-05)
Sexdum	0.045	-0.008	0.166**	-0.003	0.013
	(0.03)	(0.03)	(0.08)	(3.27E-03)	(0.02)
constant	-1.485***	-1.357***		-0.045**	-0.306***
	(0.12)	(0.16)		(0.02)	(0.09)
Pseudo R2	0.0901			0.2497	0.1610
No. of observations	5978	5978		1604	3813
Log likelihood	-3790.97	-3625.00			

Note: **,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

Table (C): Additional robustness tests for the null effect of marginal tax rate

	Tobit	Heteroscedastic Tobit		Quantile 0.6	Quantile 0.8
Variables		coefficient	$\boxed{\gamma}$		
Allocation1995	0.491***	0.45***	-0.115	0.544***	0.489***
	(0.04)	(0.04)	(0.13)	(0.03)	(0.04)
Marginal tax rate 2000	-0.230	0.265	-1.991**	0.323	-0.489*
	(0.26)	(0.26)	(0.92)	(0.20)	(0.27)
Netliquidwealth	0.526***	0.764***	-1.735***	0.543***	0.281***
	(0.08)	(0.11)	(0.27)	(0.06)	(0.08)
Netliquidwealth squared	-0.109***	-0.321***	0.703***	-0.128***	-0.056***
	(0.02)	(0.07)	(0.13)	(0.02)	(0.02)
Personaldebt	1.202***	1.303***	-1.629	1.149***	0.834***
	(0.33)	(0.30)	(1.31)	(0.23)	(0.29)
Housing	0.121***	0.161***	-0.444***	0.125***	0.033
	(0.04)	(0.04)	(0.14)	(0.03)	(0.04)
Housingsquared	-0.021***	-0.029***	0.064**	-0.024***	-0.011

	(0.01)	(0.17)	(0.03)	(0.01)	(0.01)
Outstanding mortgage	0.107***	0.139***	0.231*	0.114***	0.173***
	(0.04)	(0.04)	(0.14)	(0.03)	(0.04)
Grossincome	0.077	-0.267	0.402	-0.442***	0.198
	(0.19)	(0.17)	(0.69)	(0.14)	(0.18)
Incomenlw	1.10E-04***	2.04E-04***	3.13E-04	5.19E-05***	9.95E-05***
	(4.03E-05)	(5.37E-05)	(3.23E-04)	(1.43E-05)	(2.45E-05)
Age	0.036***	0.047***	-0.053**	0.029***	0.036***
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
Agesquared	-3.28E-04***	-4.38E-04***	0.001**	-2.96E-04***	-3.35E-04***
	(7.05E-05)	(5.12E-05)	(2.65E-04)	(6.58E-05)	(7.38E-05)
Aleveldum	0.044	0.027	-0.013	0.013	0.050
	(0.03)	(0.03)	(0.11)	(0.03)	(0.04)
Degreedum	0.076*	0.087**	-0.241*	0.054*	0.016
	(0.04)	(0.04)	(0.14)	(0.03)	(0.05)
Pensiondum	0.039	0.079*	-0.161	0.033	0.009
	(0.04)	(0.04)	(0.14)	(0.03)	(0.04)
Employeedum	-0.069	-0.144**	0.413*	-0.061	-0.039
	(0.07)	(0.07)	(0.23)	(0.05)	(0.07)
Selfemployeddum	-0.169**	-0.177***	-0.233	-0.141***	-0.199**
	(0.07)	(0.06)	(0.23)	(0.05)	(0.08)
Unemployeddum	-0.195**	-0.206**	0.01	-0.159*	-0.195**
	(0.08)	(0.10)	(0.32)	(0.08)	(0.09)
Sexdum	0.033	0.003	0.238**	0.063***	0.051
	(0.03)	(0.03)	(0.10)	(0.02)	(0.03)
Maritaldum	-0.009	-0.030	0.075	-0.029	0.028
	(0.03)	(0.03)	(0.12)	(0.03)	(0.04)
Childdum	0.145**	0.129**	0.135	0.164***	0.124*
	(0.06)	(0.06)	(0.23)	(0.05)	(0.07)
Numberofkids	-0.043	-0.047	-0.022	-0.065***	-0.021
	(0.03)	(0.03)	(0.11)	(0.02)	(0.03)
Londondum	-0.018	-0.033	-0.053	-0.059	0.028
	(0.05)	(0.04)	(0.16)	(0.04)	(0.05)
Youngunhealthdum	0.007	-0.013	0.236	-0.014	0.084
	(0.14)	(0.22)	(0.63)	(0.12)	(0.14)
Oldhealthdum	0.050	0.134*	-0.31	0.093	0.044
	(0.07)	(0.08)	(0.24)	(0.06)	(0.08)
Oldunhealthdum	-0.349	0.142	-2.211	0.197	-0.122
	(0.23)	(0.19)	(1.54)	(0.17)	(0.20)
Healthstatus	-0.003	-0.012	0.135**	0.005	-0.003
	(0.02)	(0.02)	(0.06)	(0.01)	(0.02)

Constant	-1.089***	-1.339***		-0.760***	-0.551***
	(0.16)	(0.20)		(0.15)	(0.16)
Pseudo R2	0.1288			0.1663	0.149
No. of observations	2203	2203		1558	2175
Log likelihood	-1745.65	-1666.00			

Note: **,**,*** indicates the coefficient is significantly different from zero at the 10%,5%, and 1% level, respectively. Standard error is presented in parentheses. Netliquidwealth, Personaldebt, Housing and Grosslabourincome are measured in £100,000 in the above regressions, whereas Netliquidwealthsquared and Housingsquared are the squared terms for Netliquidwealth and Housing which are measured in £100,000 respectively.*

6.Conclusion

6.1 Summary of Results

In conclusion, by using the BHPS data we have carried out three empirical studies to investigate the household risky asset choice in the UK. The first study in Chapter 3 identifies variables or factors that can be observed to influence a household's asset choice through parameters of their objective function such as risk aversion and habit. The second study in Chapter four finds that retirement has positive effect on risky asset shares for house owners while it has no effect on non house owners. The third study in Chapter five find in the short run paying income tax has negative impact on individual's risky asset shares and in the long run paying capital gain tax has positive effect on individual's risky asset shares.

In Chapter three, we have analysed empirically household-specific factors that influence the extent to which household hold risky assets. Using a typical model of asset choice our empirical specification identifies variables that can be observed to influence a household's asset choice through parameters of their objective function such as risk aversion and habit. Net liquid wealth, personal debt, housing wealth, outstanding mortgage, the ratio of income to net liquid wealth, age and employment status are observed to influence a household's risk aversion. Factors such as education, pension, gender, marital status, number of children and location are found to be insignificant variables. Specifically, except for the very wealthy, net liquid wealth has a positive impact on households' risky asset shares. This result is consistent with decreasing risk aversion as individual become wealthier. The inversed-U shape impact of housing wealth on risky asset shares can be explained by the overall effect from three sub-effects, namely, the negative house price risk, the negative housing consumption commitment effect and positive housing wealth effect, which we have detailed in the Literature survey of chapter 2.7.1. The positive influence of debt (personal debt and outstanding mortgage) suggests that the financial sophistication of the household is a determinant to the extent to which they invest in risky assets. The positive effect of the ratio of annual labour income to net liquid wealth implies that as households have more income relative to their wealth they are in a better position to meet habit level consumption or respond to really bad economic shocks. Hence they can hold a more risky portfolio. In addition, this study confirms the response of asset choice to age. Specifically, as individuals age they increase their share of risky asset although above a certain age, 56 in this study, the risky asset share declines. The positive relationship between age and risky asset share could be explained by risk aversion or through habit. In other words as individuals age their habit level of consumption does not grow as quickly as their income and hence risk aversion declines. Finally, employment status is seen to be important in the context of a negative influence of unemployment and being self-employed. It seems likely that such an effect comes from the effect that these two employment states have on the probability of falling close to habit level of consumption with the consequent rise in risk aversion.

In Chapter Four, by carrying out an analysis including cross-sectional regression and DD estimation, we find that retirement has a positive effect on risky asset shares for house owners while it has no effect on non-house owners. Furthermore, by implementing a short panel study on the joint impact of retirement and housing ownership, we find that on average, retired house owners hold the highest proportion of risky assets among the four categories of households defined in the paper, followed by employed house owners who hold the second highest proportion of risky assets. The average risky asset shares of the other two categories of households, namely, retired non house owners and employed non house owners are relatively the same and are the lowest among all. These results are statistically significant.

In Chapter Five, the impact of taxation is considered in detail using household level datasets. Firstly, from a theoretical perspective, we examine the impact of taxation on households' asset allocation. Two sub-effects, namely, substitution effect and wealth effect, will work together to determine the overall impact of taxation. We then use BHPS data to carry out an empirical study. We examine the impact of tax allowances and marginal tax rates on portfolio shares in risky assets by using the Difference-in-Difference method. After controlling for demographic factors, we found in the short run paying income tax has negative impact on individual's risky asset shares, which is significantly different from zero at the 1 percentage level. We also found in the long run paying capital gains tax has a positive effect on an individual's risky asset shares, which is also significantly different from zero at the 1 percentage level. In contrast, by using DD estimation methods, we found neither marginal income tax rate nor marginal capital gains tax has effect on risky asset shares. Furthermore, this null effect of marginal tax on risky asset shares has also been found in the standard Tobit regression for 2000 when we followed Poterba and Samwick (2003) and calculated the marginal tax rate for each individual.

6.2 Policy Implication

The purpose of the thesis is to look at social factors and how they influence portfolio selection. Hence much of the policy implications come from considering the household specific factors that are found to have an empirically significant effect on risky asset choice.

Firstly, we find that age has a non linear impact with risky asset share increasing up to the mid 50's and then falling after that. This gives us insights into the impact of an ageing population on risky-asset choice and suggests that as the average age of an economy increases we shall see greater holdings of risky assets while as the proportion of people over 60 rises the holding of risky assets will fall.

Secondly, we have observed that housing is also an influence on risky asset holdings. Many households see housing as part of their wealth portfolio and our results indicate that this may well be the case. Note that capital gains on housing is not taxed if it is an individual's main home. Hence individuals may have an incentive to invest in housing rather than financial assets which distorts the housing and share markets.

Thirdly, education level is also found to have a significant influence on asset holding. This suggests that the higher the education level you have achieved the more sophisticated your investment decisions are. If policy is to increase the spread of share ownership then enhancing financial sophistication through targetted training programmes may be helpful.

Fourthly, we find that after controlling for demographic factors, paying income tax has negative impact on individual's risky asset shares, which is significantly different from zero at 1 percent level. In contrast, we do not find the effect of marginal tax rate on risky asset shares. This leads us to draw a possible policy impaction on increasing income tax allowances which would provide tax incentive to encourage low income households to save and save in a more balanced portfolio of low and high risky assets.

We explain the last two policy implications in more detail in the following sub-section 6.2.1 and 6.2.2, respectively.

6.2.1 financial education and ensure low income households have a minimum safety net

There are clearly some policy implications that can be drawn about the way in which portfolios are structured and the extent to which incentives to hold a diversified portfolio are constrained by various household characteristics. If we would like to promote wealth holding among the lower income groups of society then the results of this thesis suggest that we need to provide more support to such households in terms of financial education and in ensuring that they have a minimum safety net which will protect them should stock returns be low or negative. The reason is that low income households as well as many other households tend to be unsophisticated and are likely to hold unwell diversified portfolio, Providing targettted training programmes and possible educations on financial capacity may enhance individuals' financial sophistication and help them to understand the financial markets, take advantage of stock markets, make wise financial investment decisions and manage their asset portfolio more efficiently. On the other hand, providing the minimum safety net can also encourage low income households to participate in stock market. The possible channels could be, for example, no capital gains tax, complete "offset privileges for capital losses" (Tobin, 1958, p82), and no tax on dividends and saving income.

6.2.2 Income tax personal allowances matter for household portfolio choice[43] (Kong and Dickinson, 2011)

Except the direct action such as social security benefits and housing subsidies, a long-term policy to help those on low incomes become better off is likely to require a more financially sustainable approach. One way of achieving this is to provide incentives for people on low incomes to save, and to save in a balanced portfolio of low and high risky assets. Providing tax incentives is one potential policy tool in this area. Current policy initiatives such as ISAs are designed to increase incentives to save. We are interested in the structure of savings.

Tax incentives can be provided in different ways. For example, the government could reduce the marginal income tax rates and/or increase the income tax allowances[44]. If the marginal income tax rate is reduced and the Capital Gains Tax rates remain the same, then on the one hand, the increased after tax return on investments would encourage individuals to invest more in risky assets. On the other hand, the increased wealth could lead the investor to hold a relatively conservative portfolio. Both substitution effects and wealth effects will work together to determine the overall impact of taxation on an individual's portfolio allocation. Similar effects would be

[43] This section has been published as a briefing paper for CHASM, and is available at http://www.birmingham.ac.uk/research/activity/social-policy/chasm/publications/briefing-papers.aspx

[44] Note that government policy proposals are consistent with an increase in tax thresholds.

found by increasing the income tax allowances. However, the latter will have a relatively large quantitative impact on low-income households since they have low wealth. Compared with facing a reduced marginal income tax, increasing tax allowances will take low-income households out of paying tax or, equivalently, a zero-tax regime.

According to our research[45] , tax allowances affect an individual's asset allocation more than the marginal tax rates. We find that increasing income tax allowances will encourage those on low incomes to save in a more balanced portfolio (ie: they increase their risky asset proportion). All financial markets will provide a long-term basis for the low-income households to build wealth and develop long-term financial security. We find that taxation can encourage a more balanced saving approach.

Of course, such a change would need to be funded, for example, through a relatively small tax on the more wealthy in the short term. The key aspect is that by encouraging such behaviour the long term consequences for the economy will be that low-income households will substantially benefit from having more assets and greater income and that they will pay more tax in the future as a consequence.

[45] We used individual level data from the British Household Panel Survey (BHPS) to examine the impact of tax allowances and marginal tax rates on portfolio shares in risky assets by using the Difference-in-Difference method. After controlling for demographic factors, we found paying income tax has negative impact on individual's risky asset shares, which is significantly different from zero at 1 percent level. In contrast, we found the effect of marginal tax rate on risky asset shares is statistically insignificant.

6.3 Limitation and future research

Firstly, all the empirical work, interpretation and analysis carried out in this thesis are based on assumptions that the behaviour of individuals is rational. However, irrational behaviour of individuals could take place. For example, irrational investors would "increase their portfolios as the stock market was rising and then liquidate stock as the market collapsed" [46](Farhi and Panageas, 2007, pp89). This irrational behaviour of noise trader would have impact on the asset prices and may also help to explain the cross sectional variations in risky asset holdings.

Secondly, although BHPS survey contains microdata on financial wealth and asset holdings, it is only suitable for an analysis based on two classification of household asset choice, namely, risk-free assets and risky assets. We now propose to carry out an analysis on British households' asset choices by using a new dataset from The Wealth and Assets Survey which has been available since last year.

Compared with current research dataset which is from BHPS, Wealth and Assets Survey provides much more detailed information on British Households' different asset class holdings, financial and private pension wealth, property, and savings, debt and borrowings. Its sample size is about 70,000 people, which is quite large. Demographic data will also be collected including "sex, age, employment status, socio-economic classification, geography and education" (ONS, 2010). This will allow us to consider

[46] This irrational behaviour is consistent with the observations in China which experienced a dramatically increase in risky asset holdings during the last ten years and there is a high proportion of the middle aged individuals and old population participating in the stock market boom. These individuals have accumulated a vast amount of wealth over their working life. The rapid rising in stock market and the easy access to it encourage them to participate in stock market and allocate a high proportion of wealth in it. The retirement would have a larger impact on Chinese's asset allocation behaviour than households in other developed countries since the Chinese need to accumulate relatively more wealth for later consumption due to the not-well-developed health insurance and social security system.

such factors as financial exclusion in a more detailed way than previously. Typically this is portrayed as a two state variable – either you participate in financial markets or not. But we can extend our understanding of this by relating socio-economic factors to the decision that individual's make about multiple asset choice. Including transaction costs, taxation as well will provide us with a very rich story to understand what is driving financial market participation and multiple asset choice.

Furthermore, based on our current study which is using BHPS data, we identify that net liquid wealth, personal debt, housing wealth, outstanding mortgage, the ratio of income to net liquid wealth, age and employment status are observed to influence a households' risk aversion. Factors such as education, pension, gender, marital status, number of children and location are found to be insignificant variables by using the BHPS dataset. However these factors are supposed to be correlated with risk aversion. Maybe by applying this idea on a larger dataset from Wealth and Assets Survey, we will be able to provide a more reliable examination of factors that determine risk aversion and explain the cross sectional variation in households' risky asset choices.

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